U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

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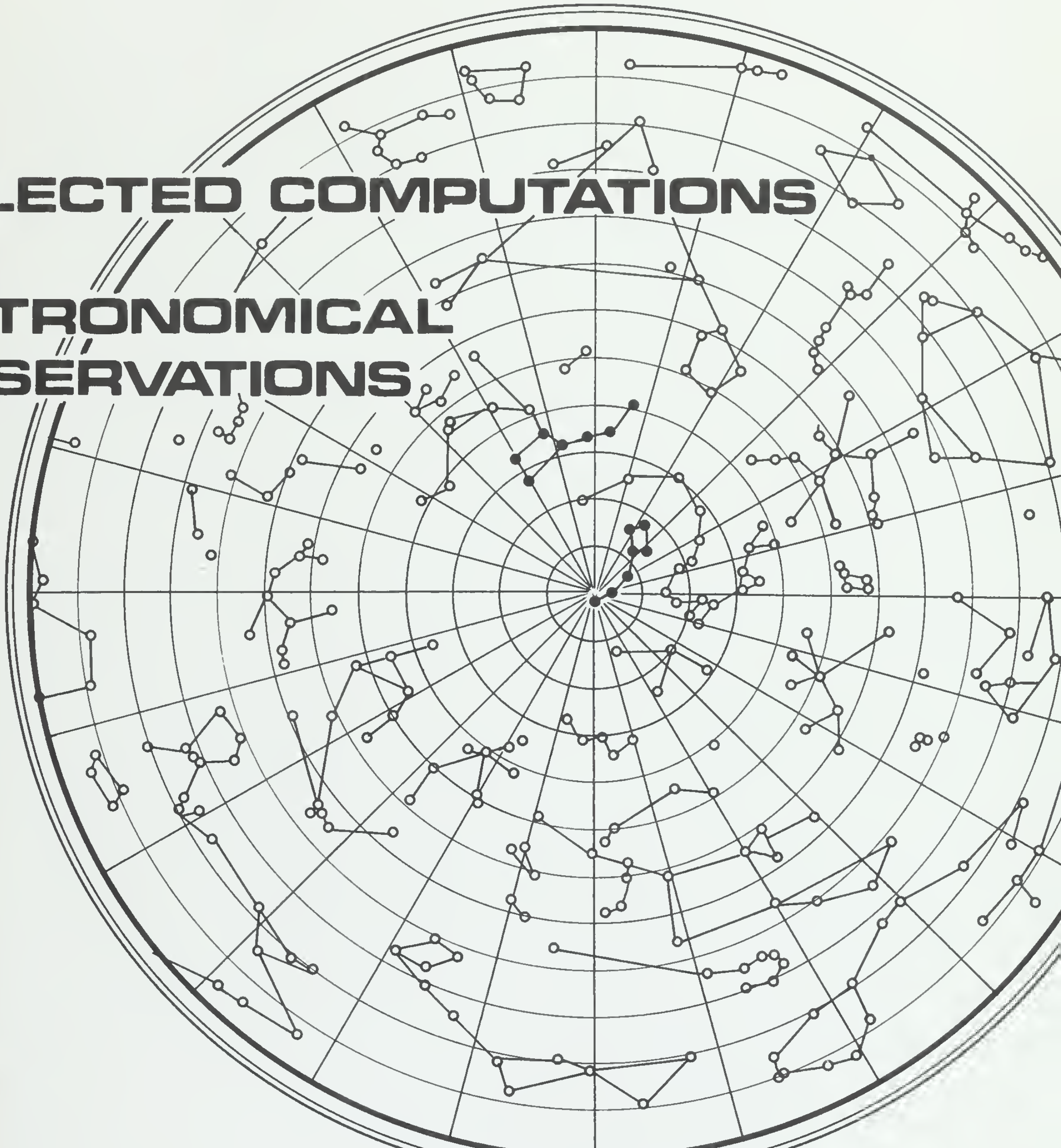
TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

SELECTED COMPUTATIONS OF ASTRONOMICAL OBSERVATIONS



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FOREWORD

This booklet was first written and compiled by C. Albert White, Cadastral Surveyor, in 1971, for use in the Cadastral Survey Training Program. Since then it has become very popular among BLM field surveyors and others.

This first revision makes this a Bureau of Land Mangement Technical Note incorporating minor changes such as the use of the Greek alphabet symbols in place of English alphabet letters and the correction of typographical errors.

The surveyor should have the Manual of Surveying Instructions, 1973, available. The 1971 Bureau of Land Management Ephemeris of the Sun, Polaris and Other Selected Stars is included as part of this technical note.

Those surveyors who have a more intense interest in the subject are referred to the book Practical Astronomy by Hosmer and Robbins, 4th edition, Wiley.

CONTENTS

NOTATIONS & ABBREVIATIONS

The following is a list of some of the notations and abbreviations used in this paper, the Manual of Surveying Instructions, and various text books. They are intended as a reference to the notations and abbreviations used in an attempt to avoid confusion concerning overlapping terms or expressions and therefore should be helpful.

The Greek Alphabet

The Greek alphabet is used to designate the brightness of stars in descending order. The alpha star is the brightest in a constellation, the beta star the second brightest, and so on. The Greek alphabet is also used to designate certain angles, such as Latitude, Longitude, Declination, etc. The most commonly used Greek letters, both Capital and lower case, are listed, with an example of the use of each.

A - α	- alpha	The Capital (A) is used to designate the Azimuth of a celestial body measured from either North OR South. The lower case (α) is used to designate the alpha star, the brightest in a constellation.
B - β	- beta	The beta star, the second brightest in a constellation.
Δ - δ	- delta	The Capital (Δ) is usually used to designate the central angle of a circular curve. The lower case (δ) designates the Declination of a celestial body. Also the 4th brightest star in a constellation.
Z - ζ	- zeta	The Capital (Z) is frequently used to designate the azimuth of a celestial body in reference to North. The lower case (ζ) designates the zenith distance of a body. ($\zeta = 90° -$ altitude)
Θ - θ	- theta	The lower case (θ) is used to designate some particular angle between two lines, such as the angle between grid North and true North in the Lambert co-ordinate system.
Λ - λ	- lambda	The lower case (λ) designates the Longitude of a place, point, or Great Circle Arc.
N - ν	- nu	(noo) The lower case designates the observed vertical angle measured from the horizon to the celestial body.
Π - π	- pi	The lower case (π) is used to designate a constant in computing functions or portions of a curve. $\pi = 3.14159265+$
Φ - φ	- phi	(fee) The lower case (φ) is used to designate the Latitude of a station or a line parallel to the equator.

OTHER ABBREVIATIONS

Some letters of the Engish alphabet commonly used to designate some certain angle, or abbreviate word statements, are:

App. T.	- Apparent Time
d, decl.	- Declination of a celestial body. (the "latitude" of the body, north or south of the celestial equator)
E.E.	- Eastern Elongation. (usually of Polaris)
Eq. T.	- Equation of Time. (difference between Mean and Apparent Sun)
GHA	- Greenwich Hour Angle. (the hour angle of the body, measured at Greenwich)
GMT, GCT	- Greenwich Mean Time, the same as Greenwich Civil Time.
h	- The true altitude of a celestial body, (h= v - refraction)
H.A.	- Horizontal Angle. (as measured in a horizontal plane)
L	- Latitude. (of a point or line)
L.A.T.	- Local Apparent Time.
L.C.	- Lower Culmination. (usually of Polaris)
LHA	- Local Hour Angle. (equivalent to the "t" angle)
LMT	- Local Mean Time.
L.S.T.	- Local Standard Time.
MTHA	- Mean Time Hour Angle. (an hour angle in mean solar time)
p	- Polar Distance. ($p = 90° - d$)
par.	- Parallax. (of the sun)
r, refr.	- Refraction. (usually intended to be refraction corrected for temperature and elevation)
R. A.	- Right Ascension. (the "longitude" of a star measured easterly from the First Point of Aries)
S	- Usually used in a formula to designate the sum of angles added together and divided by two)

SHA - Sidereal Hour Angle. (an hour angle from some point to a star measured in sidereal time interval)

sid. conv. - Sidereal Conversion. (the amount used to convert mean time to sidereal time, or the reverse. 3^m 56^s in one full day, very nearly)

S.T., Z.T. - Standard Time, the same as Zone Time.

t - The hour angle of a celestial body. On the sun "t" is the hour angle in Apparent Time. On a star "t" is the hour angle in Sidereal Time. (equivalent to LHA)

U.C. - Upper Culmination. (usually of Polaris)

U.T. - Universal Time. (the Greenwich Mean Time expressed from 0^h midnight to 24^h, or 24 hour clock)

V.A. - The Vertical Angle measured to the sun or star. (ANY vertical angle)

W.E. - Western Elongation. (usually of Polaris)

x - The co-ordinate of a point measured along the East-West axis. (the departure)

y - The co-ordinate of a point measured along the North-South axis. (the latitude)

Z - The Zenith, a point straight overhead, or 90° vertically from the horizon.

Z.D. - The Zenith Distance. (the angle between the zenith and the celestial body; ZD = 90° - h)

THE MOTION OF THE EARTH

The earth is a rather unstable platform revolving about the sun in an elliptical orbit. The earth makes one complete revolution around the sun in about 365.24 solar days. The earth rotates on its axis, a line through the poles of the earth, making one complete rotation about the axis in one day. The axis is inclined about 23½° in relation to the sun or path of orbit. Since the orbital path is elliptical in shape, the distance the earth is from the sun varies throughout the year, and the rate of speed of the earth along the orbital path varies throughout the year.

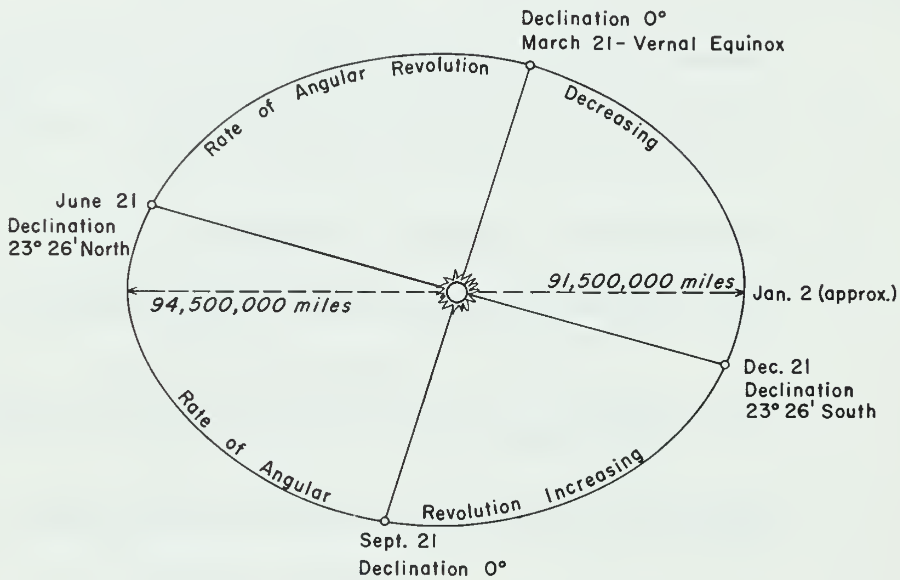

FIG. 1 - EARTH'S ORBIT AND THE SEASONS.

As indicated in Figure 1, the rate of Angular Revolution is Increasing from July thru December and Decreasing from January thru June. The earth is closest to the sun in December and the north pole is inclined <u>away</u> from the sun, with south declination at its maximum. The earth is most distant from the sun in June; the north pole is inclined <u>toward</u> the sun and north declination is at its maximum.

As indicated in Figure 2, the earth travels a greater distance along its orbital path in an interval of time in December, and a lesser distance in the same interval of time in June. In Figure 2, the interval of time between a and a' is equal to the interval of time between b and b', etc. The AREA of the shaded portions are EQUAL. The areas "swept out" by the earth in equal intervals of time are always equal. (This is known as Kepler's second law.)

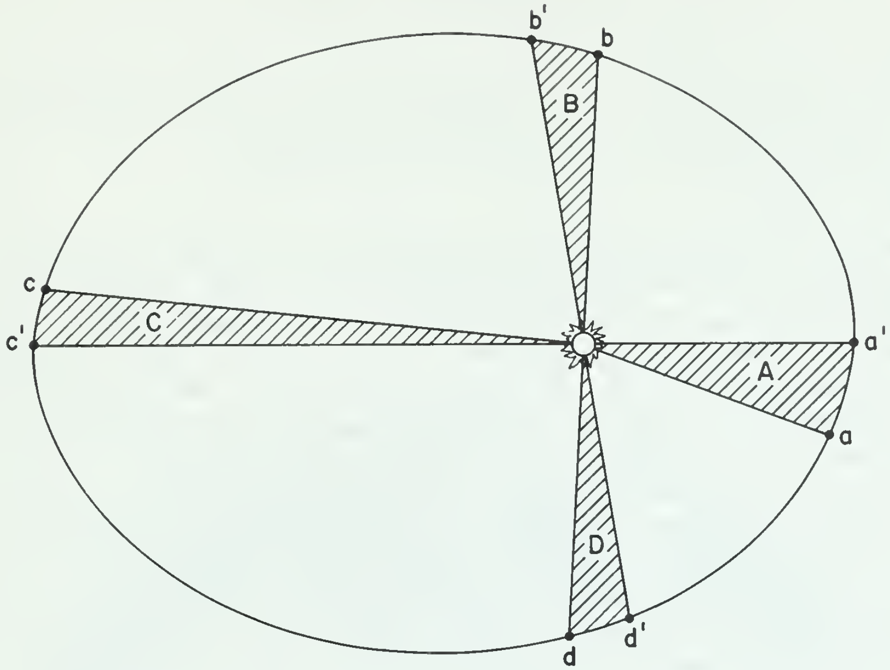

FIG. 2 - THE EARTH'S ORBITAL MOTION

So it can be seen that the earth will travel a greater, or lesser, distance along its orbital path, depending upon the distance it is from the sun. Since the rate of rotation of the earth on its axis is constant and uniform, the sun will appear to be in a different position in the sky at a given time on any given day, both in declination and time of crossing a given meridian. This, then, is the real problem to be solved: Where is the Sun or a Star?

SOLAR TIME

Apparent Time:

If we were to set up a transit on a given meridian, orient the telescope to due South, observe the instant the sun was exactly on the meridian and note the exact time; wait one day and make the same observation, noting the exact moment of meridian passage, we would have observed ONE Apparent Solar Day. If we were to repeat this process over a full year it would soon become obvious that the Apparent Solar Day varies in length, being shorter or longer in time, at different times of the year. It would be nearly impossible to build a watch that would keep accurate Apparent Time. (A sundial keeps Apparent Time but can hardly be termed "accurate".)

Mean Time:

To solve the problem of the variable Apparent Time, a MEAN of the apparent time was taken. The MEAN SOLAR DAY is a period of exactly 24 hours of Mean Time. So we then have a fictitious position of the sun in crossing the meridian called the Mean Sun. The earth makes one complete rotation on its axis in 24 Mean Time hours to be realined on the Mean Sun. It is this MEAN SUN or MEAN TIME by which all our clocks are regulated.

Equation of Time:

When we take a sun observation to compute the bearing of a line, the computations must be based upon the Apparent (true) Time, or the true position of the real sun. We time the observation with a watch which is regulated to Mean Time, or Mean (imaginary) Sun. So the Ephemeris lists the EQUATION of TIME to enable us to make the correct computations. The Equation of Time is the difference (in time) between the time of the Apparent (true) Sun crossing the meridian and the Mean Sun crossing the same meridian. The BLM Ephemeris lists the Equation of Time at the moment the Apparent Sun crosses the meridian of Greenwich at NOON of each day of the year. The amount of time is listed as being added to or subtracted from Apparent Time to arrive at Mean Time. The Equation of Time is greatest in November and is listed as "subtract from Apparent Time." In other words, the Mean sun is behind the Apparent (true) sun and the Equation of Time is subtracted from Apparent Time to arrive at Mean Time. It is more often the case that we know our Mean Time and want the Apparent Time, so the reverse process must be used, i.e., add the Equation of Time to get the Apparent Time. The Mean Sun is ahead of the Apparent Sun in July and the Ephemeris lists the Equation of Time as added to Apparent Time. Therefore, the Equation of Time is subtracted from Mean Time to arrive at the Apparent Time.

Standard Time, Longitude and Local Mean Time:

The earth is nearly spherical in shape, or round. Just as any other circle, it is divided into 360° or lines of Longitude. The zero point of the circle passes through the Royal Observatory at Greenwich, England. Greenwich is said to be at 0° Longitude and the longitudinal lines are marked off to the east and west from Greenwich, 180° in each direction. All lines of Longitude converge at the North and South poles of the earth. One complete rotation of the earth is 360° of Longitude, or 24 hours of Mean Solar Time. Therefore, in ONE Mean Solar hour the earth will rotate through 15° of longitude. Dividing this further: the earth will rotate through 1° of longitude in 4 min. of mean time, and through 1 min. of longitude in 4 seconds of mean time. The divisions are:

$$\frac{360^\circ}{24} = 15^\circ = 1 \text{ hr.} \qquad 1^\circ = \frac{60^m}{15} = 4^m \qquad 1' = \frac{60^s}{15} = 4^s$$

The term "LOCAL MEAN TIME" is used to describe mean time on a given "local" meridian in relation to Greenwich. When the MEAN sun is on the meridian of Greenwich, the Local Mean Time at Greenwich is 12:00:00 noon, but ONLY on the meridian of Greenwich. At a point in 15° West Longitude the Local Mean Time would be 11:00:00 AM, 1 hr. earlier. At the same instant at a point in 100° West Longitude the Local Mean Time would be 5:20:00 AM, early morning. See Figures 3 and 4.

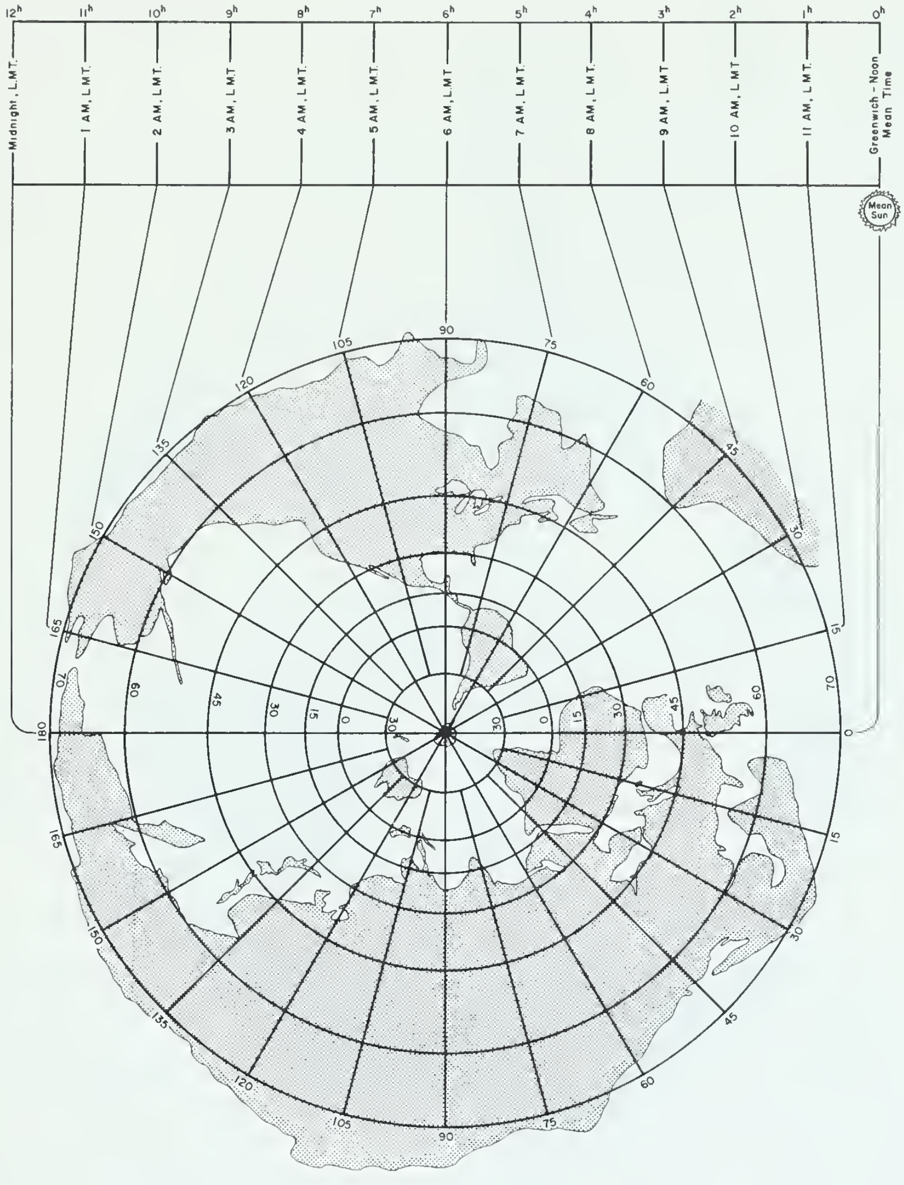

FIG. 3 - MEAN TIME AND LONGITUDE.

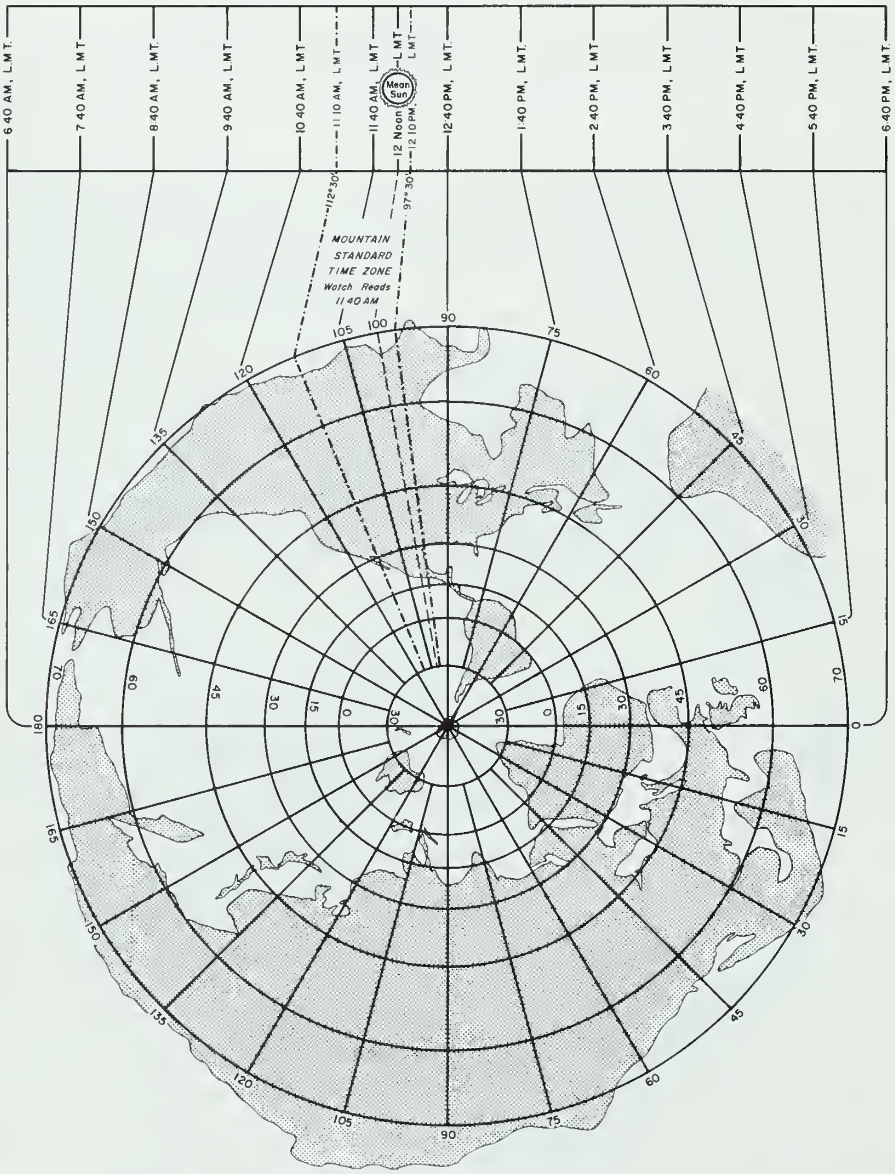

FIG. 4 - STANDARD TIME AND MEAN TIME.

If our clocks were all set for Greenwich Mean Time, and everyone went to work at (say) 8:00 AM - people living in New York would be going to work in the middle of the night. Such a system wouldn't be very workable. If we all went to work by Local Mean Time, a person living in Longitude 100° West would leave home 4 minutes earlier than another person living about 50 miles away in Longitude 101° West. Such a system would be almost as confusing as the first, for everyone not living on exactly the same meridian would have a different time registered on his watch. To standardize clocks, the Standard Time Zone system was devised in increments of 1 hour. The world is divided into 24 Standard Time Zones. The Central Meridian of each Zone is 15° of longitude progressively East and West from Greenwich. Each Zone is about 15° of longitude in width measured 7½° of longitude each way from the Central Meridian. The Standard Time in each Zone is the LOCAL MEAN TIME of the CENTRAL MERIDIAN. The Central (zone) Meridians in the United States are: 75° (Eastern), 90° (Central), 105° (Mountain), 120° (Pacific), 135° (Yukon), 150° (Alaska) and 165° (Bering). The zone lines DO NOT follow a meridian exactly 7½° to the left and right of the Central Meridian because of political and economic reasons. (All of Arizona is on Mountain Time, whereas, nearly half the State is West of 112½° Longitude.) Therefore, it is important to know which Zone Meridian your watch is set for.

To change Standard Time to Local Mean Time, the difference in Longitude between the Longitude of the Zone Meridian and the Local Meridian <u>must</u> be known and converted to units of time. (The conversion tables on Ephemeris page 27 may be used for this purpose.) If the Local Meridian is <u>West</u> of the Zone Meridian, the <u>difference</u> is <u>subtracted</u> from Standard Time to arrive at Local Mean Time. If the Local Meridian is <u>East</u> of the Zone Meridian, the <u>difference</u> is <u>added</u> to Standard Time to arrive at Local Mean Time. Just reverse this process to change Local Mean Time to Standard Time.

Elapsed Time:

Some confusion occurs in determining elapsed time for purposes of computing the declination of the sun (or equation of time) at the moment an observation is made on the sun. For purposes of using the BLM Ephemeris, elapsed time is the amount of time that has elapsed since it was Apparent Noon at Greenwich. Probably the easiest way to visualize, or compute, elapsed time is to equate your Standard Time to the time of Greenwich Mean Noon and then apply the Equation of Time in the proper direction. Since Local Mean Time at Greenwich is also Standard Time at Greenwich, if your watch is set for (say) 7 hrs. prior to Greenwich then your watch will always read just 7 hrs. earlier. So if it is 12:00 noon Local Mean Time in Greenwich your watch will read 5:00 AM, 7 hrs. earlier, and will read that time regardless of where you are located. So if you take an observation when <u>your</u> watch reads 8:00 AM, the Standard <u>and</u> Local Mean Time in Greenwich is 3:00 PM and 3 hrs. of Mean Time has elapsed. However, the BLM Ephemeris lists the declination and equation of time for <u>Apparent Noon</u> Greenwich, and we need the elapsed <u>Apparent Time</u> for computing declination. Since the Equation of Time is listed in relation to Apparent Time, we must apply the Equation of Time to the 3:00 hrs. of Mean Time. If the Equation of Time is listed in the Ephemeris to be ADDED to Apparent Time, then it must be SUBTRACTED from the elapsed MEAN Time to arrive at the elapsed APPARENT TIME. If the Equation of Time is listed as $0^h\ 10.0^m$ to be added to Apparent Time,we would have to subtract $0^h\ 10.0^m$ from our elapsed Mean Time and (in this case) our Elapsed Apparent Time interval would be $2^h\ 50^m$. This process is illustrated in Figure 5.

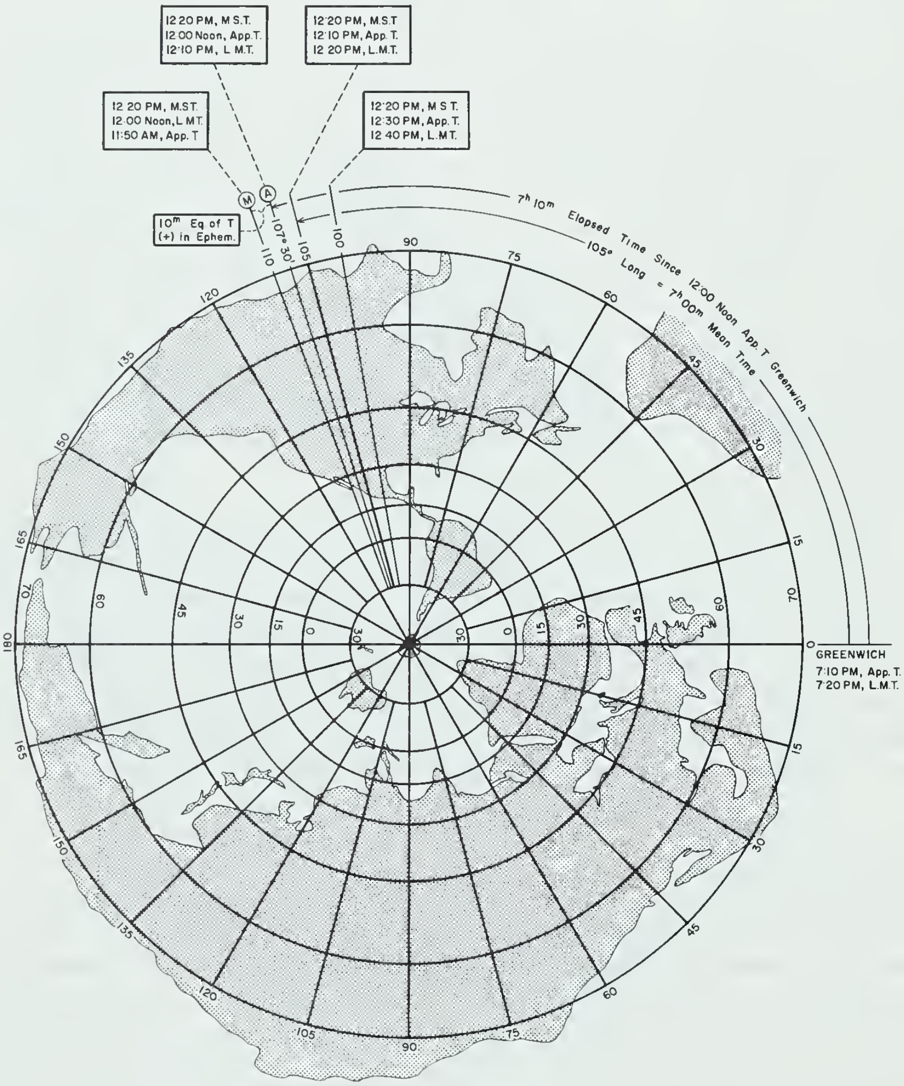

FIG. 5 - APPARENT TIME, MEAN TIME AND "ELAPSED TIME".

SIDEREAL TIME

Astronomers use another system of keeping time called Sidereal Time (from the Latin, sidereous: relating to the stars). The stars are so far from the earth that they appear to be "fixed" in position. Unlike the sun they DO NOT NOTICEABLY change in declination in one day or even one month or year. They DO change slightly in position, but the change is very slight and is "taken care of" in the Ephemeris tables. A Sidereal Day is 24:00 hrs. of Sidereal Time. The earth makes one complete rotation in one Sidereal Day, the period of time between two successive passages of the Vernal Equinox over a given meridian.

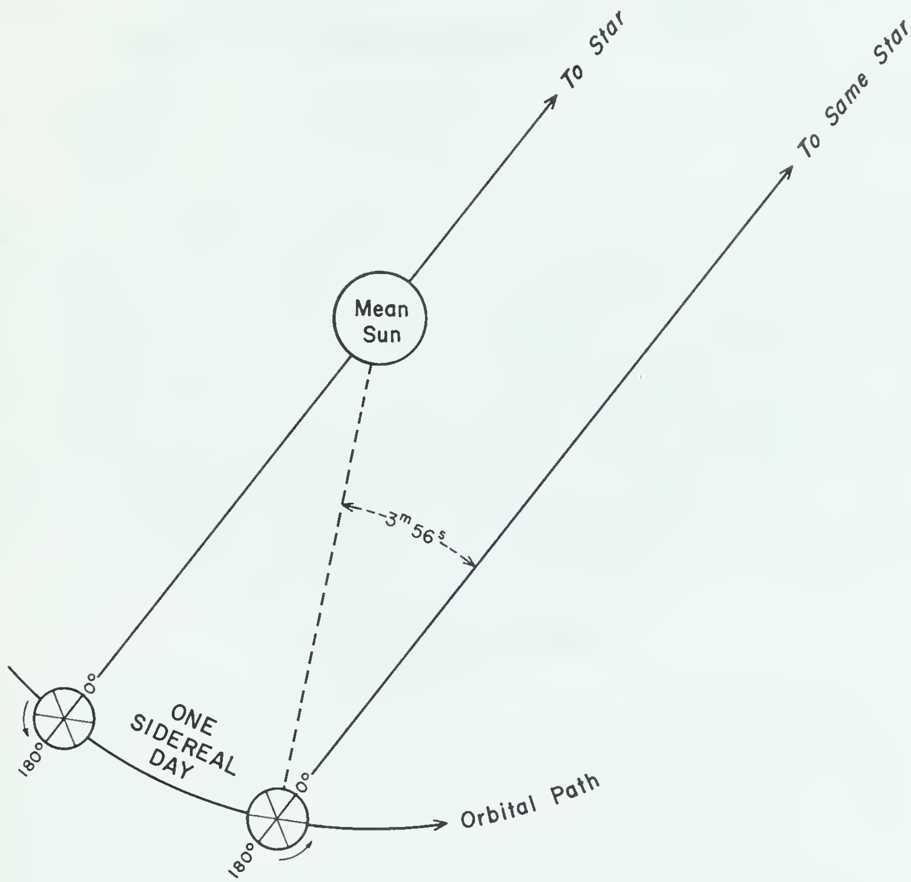

FIG. 6 - SIDEREAL DAY AND CONVERSION TO MEAN SOLAR TIME.

There are 366.2422 Sidereal Days in one year of 365.2422 mean solar days. One Sidereal Day is equal to 0.99726957 mean solar days. 24:00:00 hrs. of Sidereal Time is equal to $23^h\ 56^m\ 04^s$ (very nearly) of Mean Solar Time. A Solar Day is based upon one complete rotation of the earth in relation to the Sun. But during that Solar Day the earth has moved 1/365.2422 of the circumference of its orbit about the mean sun. So the earth has to turn about $3^m\ 56^s$ further each day to be "lined up" on the mean sun than it does to be "lined up" on a given star. This is illustrated in Figure 6. So a Sidereal Day is $3^m\ 56^s$ shorter than a Mean Solar Day, or a Mean Solar Day is $3^m\ 56^s$ longer than a Sidereal Day. Therefore, a star will cross the meridian of Greenwich (or any other meridian) $3^m\ 56^s$ EARLIER each day than it did the day before, measured in Mean Solar Time. 24:00:00 hrs. of Sidereal Time would have passed but only $23^h\ 56^m\ 04^s$ of Mean Solar Time would have elapsed. Another way of saying this: The stars APPEAR to be moving faster than the sun by $3^m\ 56^s$ per day.

The difference between Sidereal Time and Mean Solar Time is called the SIDEREAL CONVERSION listed on page 27 of the BLM Ephemeris.

If a Star and the Mean Sun both transit (cross) the Greenwich Meridian at the same instant on a given day, and since they both APPEAR to speed westerly around the earth, the Star would GAIN on the Mean Sun. As illustrated in Figure 7, the Star would arrive at 105° W. Longitude ($7^h\ 00^m\ 00^s$ of elapsed mean time) $1^m\ 09^s$ sooner than the mean sun, as measured in Mean Solar Time. In other words: $7^h\ 00^m\ 00^s$ of SIDEREAL Time would have elapsed but only $6^h\ 58^m\ 51^s$ of Mean Time would have elapsed. The $1^m\ 09^s$ is a straight proportion of the total for a full day, i.e., 105/360 of $3^m\ 56^s$. This proportional rate is the same for any other elapsed time or longitude. Therefore, in longitude 135° W the proportion would be 135/360 of $3^m\ 56^s = 1^m\ 29^s$, and so on. The table of conversions is much easier to use, of course, than to compute the conversion directly.

THE 24 HOUR CLOCK

For practical purposes it was decided to change the civil date at midnight of each day, or when the mean sun is at Lower Transit. Midnight is 0^h, the beginning of a day. The hours are counted from that moment up to 12^h, or noon, then started over again so that we have the AM and PM hours. There doesn't seem to be any practical reason for starting over again at noon, unless it's for purposes of building clock mechanisims and faces. As will be seen in the discussion on Azimuth Determination, for the surveyor it is much easier to calculate elapsed time, mean time, hour angles, etc., using the total 24 hour day. 1 PM is then 13:00 hrs., 5 PM is 17:00 hrs., and so on. If a star transits the local meridian at 10:00 AM and we make an observation on it at 5 PM, the difference between the two times is, of course, 7 hrs. But the subtraction could NOT be made directly. It would be much easier, and less subject to error, if we said the star was at transit at 10:00 hrs. and we observed it at 17:00 hrs. The subtraction is then direct: 17:00 - 10:00 = 7:00 hrs. So just ADD 12 hours to all PM times of observation, etc., and all the times will be counted from midnight and be on the same basis.

There is no reason either (for the same reasons) to limit our time to a maximum of 24 hrs. If I said my time was 26:00 hrs. from midnight of the first day of the month, wouldn't that equate to 2:00 hrs. on the second day

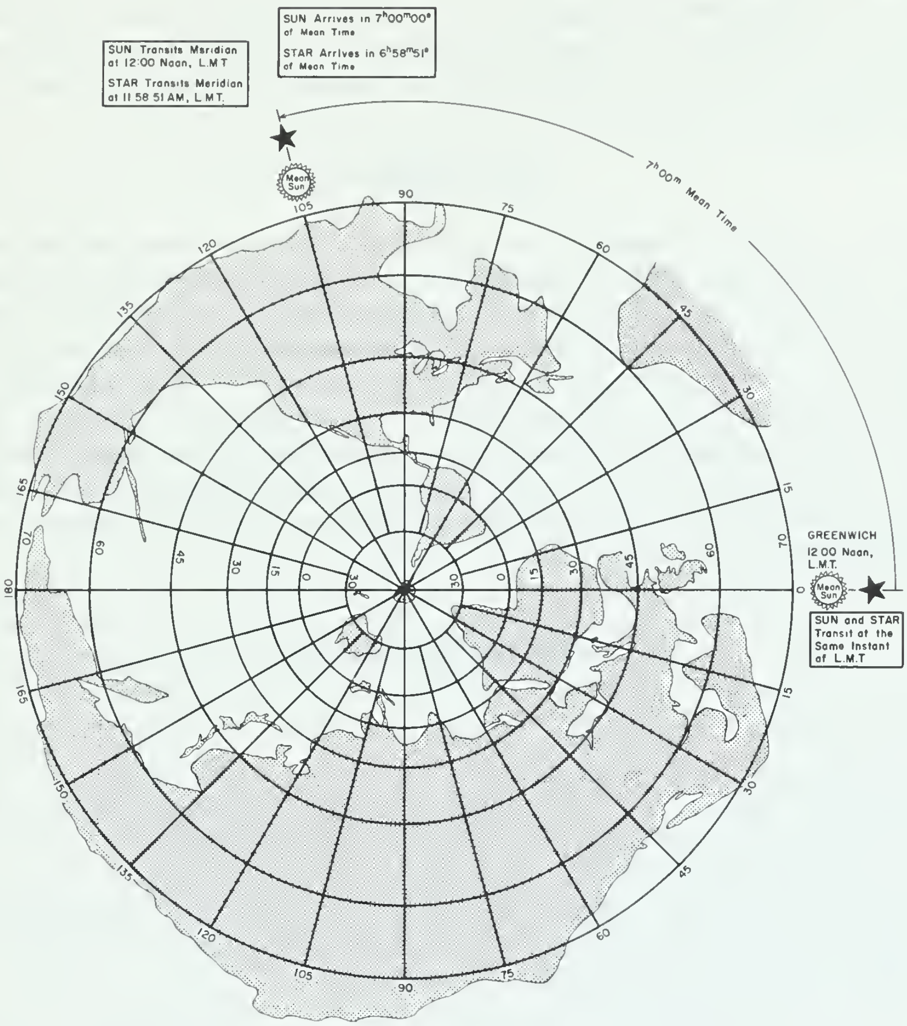

FIG. 7 - MEAN TIME OF STAR'S TRANSIT.

of the month? Since the Hour Angles of Polaris are to be computed for time After OR Before Upper Culmination, it is better to compute the hour angle from the same base. If an observation is made on Polaris at 21:00 hrs. on the 1st day of the month and the star is at Upper Culmination at 2:00 hrs. on the 2nd, no direct subtraction can be made. But 2:00 hrs. on the 2nd is 26:00 hrs. counted from midnight of the 1st, and the direct subtraction is: 26:00 - 21:00 = 5:00 hrs. The Hour Angle PRIOR to Upper Culmination is 5:00 hrs. This situation will be seen in the "Examples of Polaris" later in this paper.

TIME SIGNALS

Time signals are broadcast on shortwave radio over station WWV, Fort Collins, Colorado, on 2.5, 5, 10, 15, 20 and 25 megacycles of the shortwave band. There is a voice announcement **every** minute with the intervening seconds "ticked off." The precise Greenwich Mean Time is announced. For purposes of this paper the time given can be considered to be absolute and exact. Anyone possessing even a simple shortwave radio can time his observations accurately by comparison with the time signal. Hour Angle observations are based upon accurate time and a time signal check would be essential. The amount of time the watch is fast, or slow, can then be applied to the recorded time of observation.

AZIMUTH DETERMINATION

Direct Solar Altitude Observations:

The basic observation employed by most surveyors is the direct solar observation in which the principal factor is the vertical angle, or altitude, of the sun. The reasons for the popularity of this method are:
1) The observation can be made at convenient hours of the day.
2) Everything is visible: plates easily read, flagged lines need no lighting.
3) Precise time is not required, nor accurate longitude.
4) Familiarity with the formulae and computations.

An altitude observation on the sun will produce reliable azimuth if properly executed. There are some drawbacks, however. Precise azimuth cannot be determined by this method. Due to the size of the sun, precise pointing is nearly impossible. There is no "check" except another observation on the same line. Two observations, one in the AM and another in the PM, near equal altitude should always be made. The sun should be at least 2 hrs. away from Apparent Noon and the vertical angle should be above 25°, if possible. The sun is very difficult to observe above 50° of vertical angle, so the "range" of desirable positions for observation is somewhat restricted, though not seriously so.

Sections 105 thru 108 of the 1947 MANUAL describe a good procedure for making direct altitude observations. The only apparent exception is that for transit telescopes equipped with the "solar circle." The pointings are to center the sun instead of observing opposite limbs. Timing of the six pointings should be uniform. An experienced observer will "automatically" time his pointings. If one is inexperienced it is recommended that the recorder "count off" the time for the observer. In this way the pointings can be spaced at even intervals. After the three direct and three reverse pointings are completed the resulting three "sets" are meaned. If the spacing between pointings was uniform and the pointings accurately made (and no errors made in reading the verniers), the means of each set should be very nearly equal. A "bad" set is readily detected and can be rejected, if desired, or computed separately. (Each surveyor has his own "system" and no ONE method will be promoted here.) If the sets are nearly numerically equal they are averaged and the average value used in computing the azimuth of the sun. Once the azimuth (or bearing) of the sun is determined, the average horizontal angle turned to the sun during the observation is converted to the bearing (or azimuth) of the line or initial reference point.

The timing of an altitude observation is not critical. The local Standard Time of observation to the nearest minute is usually close enough. The declination is computed on elapsed Apparent Time since Apparent Noon Greenwich. Since the maximum hourly change in declination is about 59", a one minute error in time will only cause the computed declination, at observation, to be in error by a maximum of 1". The longitude of the station is not really required in computing the declination. For example: If an observation was made on a day when the declination listed in the Ephemeris at Apparent Noon Greenwich is 10° 00' 00" S., increasing; Hourly change of 54.00"; Equation of Time of $15^m\ 00^s$, subtractive from Apparent Time; Average time of observation 8:45 AM, with the watch set for Mountain Standard Time; (7 hrs. from Greenwich) Latitude 35°; Longitude unknown. Then, since the watch is set to read 7 hrs. from Greenwich it will read 5:00 AM Mean Time when it is Mean Noon in Greenwich regardless of where the observer might be in longitude. The observation was made at 8:45 AM, so $3^h\ 45^m$ of <u>Mean Time</u> has elapsed since it was Mean Noon in Greenwich. The Equation of Time is subtractive from Apparent Time so it must be ADDED to Mean Time, and $3^h\ 45^m$ plus $15^m = 4^h\ 00^m$, the amount of Apparent Time (nearly) that has elapsed since it was Apparent Noon in Greenwich. The declination is changing 54" per hour, so in 4 hrs. it would change 216" or 3' 36". The declination is increasing so the declination at the time of observation would be 10° 03' 36" S., the quantity used in the computations of the PZS triangle. This, then, is the usual procedure in calculating the declination. ELAPSED APPARENT TIME IS REQUIRED.

However, if <u>more</u> than <u>12 hours</u> of Apparent Time have elapsed since it was Apparent Noon in Greenwich, the declination should be computed BACK from Greenwich Noon of the FOLLOWING DAY. For example, if 16 hrs. have elapsed instead of using 16 hrs. multiplied by the hourly change in declination for the day of observation, use 8 hrs. multiplied by the hourly change for the NEXT day and come BACK from the listed declination for Noon Greenwich of the following day. The calculated declination will then be closer to the TRUE value at the time of observation.

The only other computation necessary to obtain true values is to reduce the observed vertical angle to the true altitude. The temperature at the time of observation and elevation of the observing station should be known. The tables on Ephemeris page 25 are employed. The refraction listed in the table is corrected by multiplying by the coefficients listed for the appropriate temperature and elevation. The corrected refraction is always SUBTRACTED from the observed vertical angle. The suns parallax is then ADDED and the result is the True Altitude. Knowing the Latitude of the station (or scaling it from a quad map), the altitude formulae computations can then be performed. The examples later in this paper show the methods outlined here and the actual computations.

Solar Hour Angle Observations:

An Hour Angle observation on the sun (or a star) is one in which the position, or azimuth, is determined by time. The position of the sun (and of course the stars) has been accurately plotted by astronomers. The sun will be at some known position in the sky at any given moment. If we observe a horizontal angle from some fixed point on earth, turned to the sun, and record the time of observation, the azimuth of the line to the point can be computed. The Hour Angle can be equated to the amount of time that will pass, or has passed, until or since, the sun will be, or was, exactly on the meridian of the observer. This is usually referred to in most texts as the LOCAL HOUR ANGLE. In the various formulae the Local Hour Angle is abbreviated "t". When making an Hour Angle observation on the SUN, the Local Hour Angle must be the interval of APPARENT TIME that will pass, or has passed, until the sun will be, or has been on the Local Meridian. To compute this interval accurately, accurate time must be known or obtained, the Longitude of the station must be known, and the Equation of Time must be interpolated for elapsed time between the amounts listed in the Ephemeris for Greenwich Noon of each day. This is a "straight" interpolation, i.e., if 12 hours have elapsed since Apparent Noon Greenwich, then the Equation of Time is midway between the amount listed for the day of observation and the NEXT day. The interpolated Equation of Time is then used to compute the Apparent Time of observation. (An example of this interpolation will be found in "Example II-Sun", later in this paper.) The difference between the Apparent Time at the instant of observation and the instant of Apparent Noon on the Local Meridian is "t", or the Local Hour Angle of the Sun. This amount of time in hours, minutes and seconds, is then converted to an equal amount of ARC, usually by the conversion table on Ephemeris page 26. It is this amount of arc that is used as the "t" value in the formulae, and together with the values of declination and Latitude, is used to compute the azimuth of the sun. The altitude is not employed at all in these computations.

So we have two methods for determining the azimuth, one by altitude of the sun, the other by local hour angle. Either method can stand by itself, independent of the other. But if BOTH methods are used simultaneously, that is, observe the altitude and at the same time record the time of each pointing to the nearest second, then both methods can be employed to determine the azimuth, and one <u>checks</u> the other. Any "bull" will show up quite readily.

Altitude Star Observations:

An altitude observation on a star is by far the easiest observation to make and compute. The time of observation is unimportant and there is no computation of the declination to be made because the declination of the stars is listed directly in the Ephemeris for each listed star. All one must do is make the observations in the same general manner as outlined for the sun and correct the vertical angle for refraction. Note that there is no parallax correction for a star. So no additional details are gone into at this time.

The advantages of star observations are many, for there are many stars available for observing. Perhaps that is the main reason that so few surveyors use the stars to determine azimuth. They can't identify the individual stars. This can easily be overcome by use of the "Star Finder" when the stars are visible to the naked eye, or the position of the star can be computed, as will be shown in the Examples later in this paper. The other reason for little use of the stars appears to be lighting and usually inconvenient hours. The stars can be observed during daylight hours on clear days without haze, but are best observed near, or shortly after, sunset, when lines of sight are still visible and the verniers can be read without lighting. Any surveyor should be capable of using the stars.

Equatorial Star, Hour Angle Observations:

An Hour Angle Observation on an Equatorial Star must be in terms of Sidereal Time Interval. In other words, the "t" value is the amount of Sidereal Time before, or after, the stars transit of the local meridian. The MEAN TIME interval is first computed, i.e., the difference between the Local Mean Time of observation and the Local Mean Time of the stars transit of the local meridian. The sidereal conversion for MEAN TIME HOUR ANGLE (Ephemeris page 27) is then ADDED to the Mean Time Hour Angle. The result is the Sidereal Time Interval which is then converted to "t". This is illustrated in Figure 8. The Mean Times of transit of various stars over the Greenwich Meridian are listed in the Ephemeris for the first and sixteenth days of each month. These times must be converted to the proper day and local meridian by use of the sidereal conversion tables. The Examples of Equatorial Stars demonstrate the process.

POLARIS

Polaris is a rather unique star because of its close proximity to the North Celestial Pole. It appears to revolve around the Pole in an east to west, counterclockwise, direction. At the present time the angular distance from the true pole to Polaris is about 0° 52' the "Polar Distance". The Polar Distance = 90° - declination. The declination of Polaris varies slightly throughout the year, and the star is apparently moving closer to the Pole due to Precession (wobble of the earth on its axis), Nutation (attraction of the moon), and Proper Motion. In about the year 2105, Polaris will have a Polar Distance of (about) 0° 27'. The diurnal (daily) circle of Polaris is a perfect circle. When the star is at its highest point due North, the star is said to be at transit or UPPER CULMINATION. The Mean Time of Upper Culmination, at Greenwich, is listed for each day in the Ephemeris. The time of Upper Culmination is basis for computing <u>ANY</u> Hour Angle of the star. When the star has apparently rotated for 6 hrs. along its diurnal path (circle), it is said to be at Western Elongation. In $11^h\ 58^m\ 02^s$ of Mean Time ($12^h\ 00^m\ 00^s$ of Sidereal Time) from Upper Culmination, the star is at its lowest point or Lower Culmination. In $23^h\ 56^m\ 04^s$ of Mean Time (24^h sidereal time) it will again be at Upper Culmination and so listed in the Ephemeris. The Hour Angle of the star is always calculated (in BLM practice) in time After, <u>OR</u> Prior to, Upper Culmination. The tables in the Ephemeris are based upon this method of computing Hour Angle.

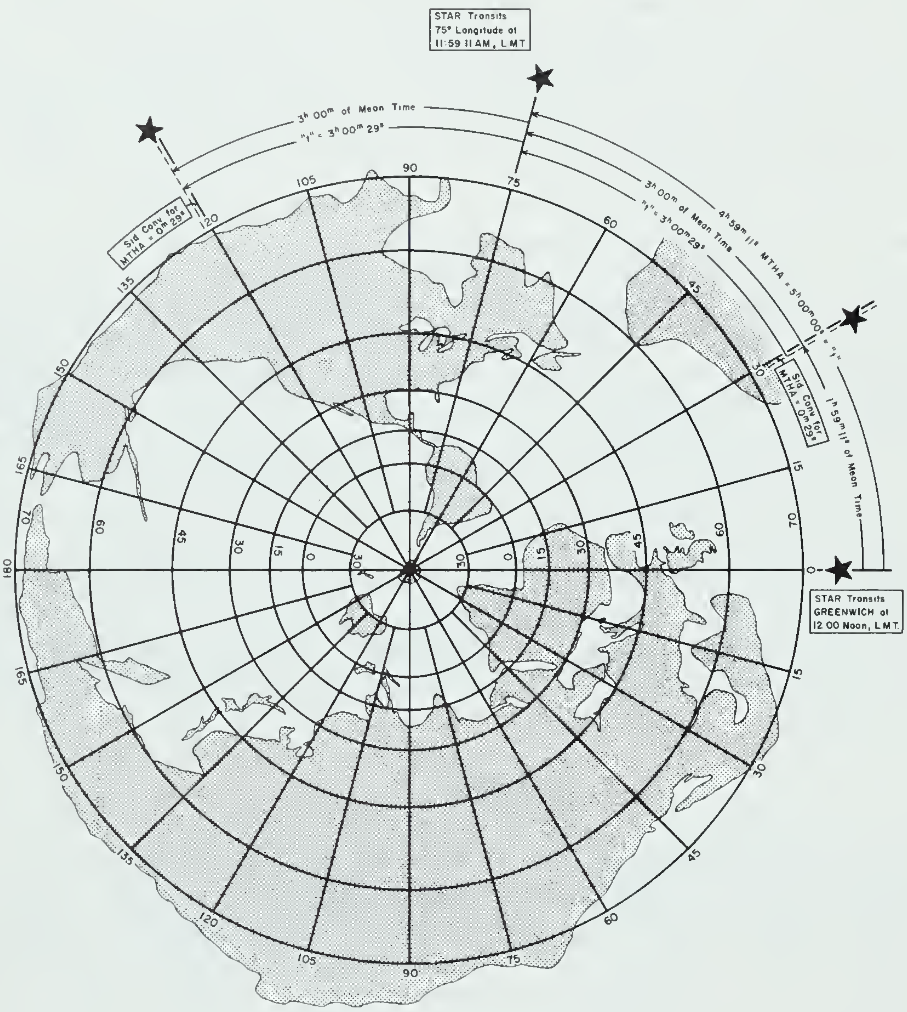

FIG. 8 - SIDEREAL CONVERSION AND "t" ANGLE.

When Polaris is at Elongation, it is about 90° to the Pole and moving straight down (W.E.) or straight up (E.E.). This is the ideal time to make an observation on the star for azimuth. Since all vertical circles intersect at the zenith, (straight overhead) a vertical plane through Polaris at Elongation will result in a different azimuth on the horizon, or horizontal plane, depending upon the Latitude of the observing station. This is illustrated in Figure 9.

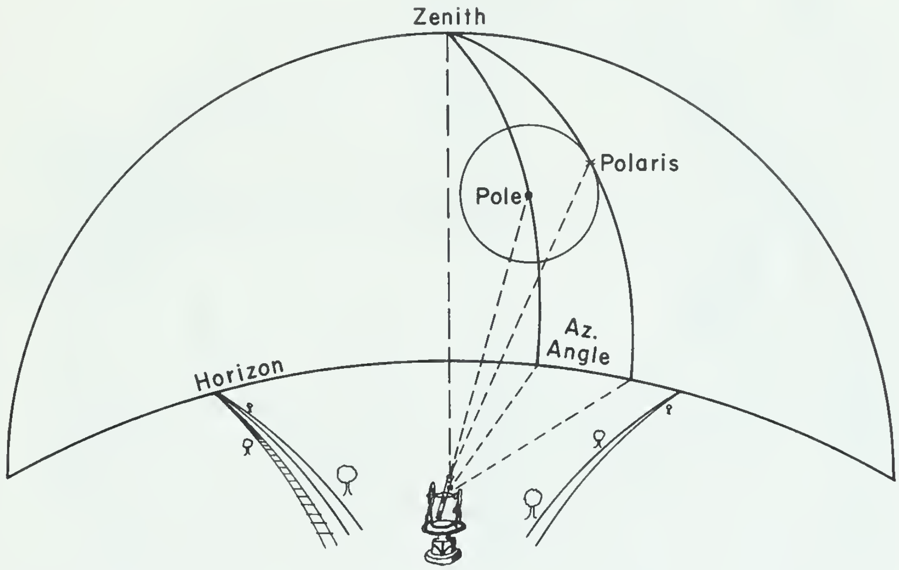

FIG. 9 - AZIMUTH OF POLARIS AT ELONGATION.

The formula for Azimuth of Polaris at Elongation is: $\text{Sin } A = \frac{\cos \delta}{\cos \phi}$. Thus, the azimuth of Polaris at Elongation at the Equator will be the Polar Distance. The azimuth will increase as the LATITUDE increases until at the North Pole it is undefined, the star would circle straight overhead. If one were to plot the azimuths of Polaris at ALL Hour Angles on graph paper for a given Latitude (40° is used in the Ephemeris), the result would be the shape of an ellipse even though the star is following a circle. For the same basic reason, the TIME of Elongation, measured from Upper Culmination, will decrease as the Latitude increases. At the equator Western Elongation would occur exactly $5^h\ 59^m\ 01^s$ in Mean Time, after Upper Culmination. In Latitude 40° North this would be reduced to $5^h\ 56.1^m$ in Mean Time (nearly) during the year 1971. The formula for computing the time of Elongation is: $\text{Cos } t = \tan \phi \cot \delta$, in which "t" is the Sidereal Time interval. Figure 10 is intended to demonstrate the Time and Azimuth of Polaris at Elongation.

The tables of "Polaris at all Hour Angles" listed in the Ephemeris are for about every 10 minute interval in MEAN TIME. The Local Mean Time of

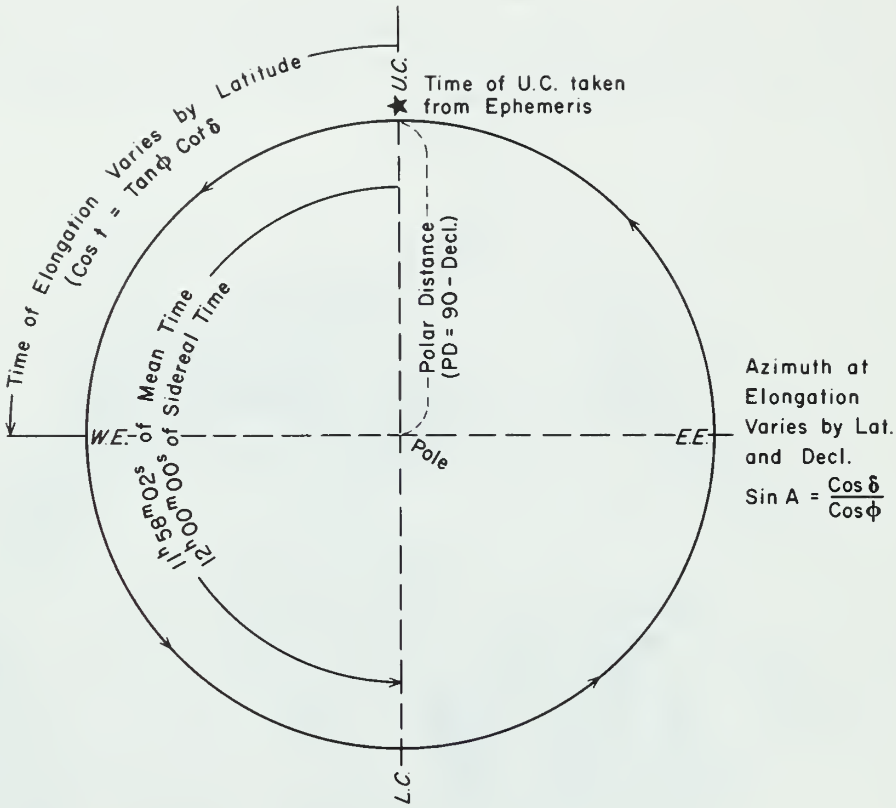

FIG. 10 - TIME AND AZIMUTH OF POLARIS AT ELONGATION.

Upper Culmination is easily computed for the local meridian. The Local Mean Time of observation is also readily determined. The difference between these two times is the MEAN TIME HOUR ANGLE of Polaris. The tables are then interpolated for this Mean Time Hour Angle between listed times and Latitudes. A slight correction is then added, or subtracted, for difference in declination.

The formula for computing the Azimuth of Polaris at a given Hour Angle is:

$$\text{Tan A} = \frac{\sin t}{\cos\phi \ \tan\delta - \sin\phi \ \cos t}$$

Again, "t" is the Local Hour Angle in SIDEREAL RATE. The Mean Time Hour Angle must be converted to Sidereal Time interval by means of the sidereal conversion, the amount being determined by the Mean Time Hour Angle. This amount is always ADDED to the Mean Time Hour Angle. Figures 11 and 12 demonstrate this conversion. The tangent of the declination changes rapidly. A table of tangents, in seconds of arc, and to at least eight decimal places is recommended for formula computations on Polaris.

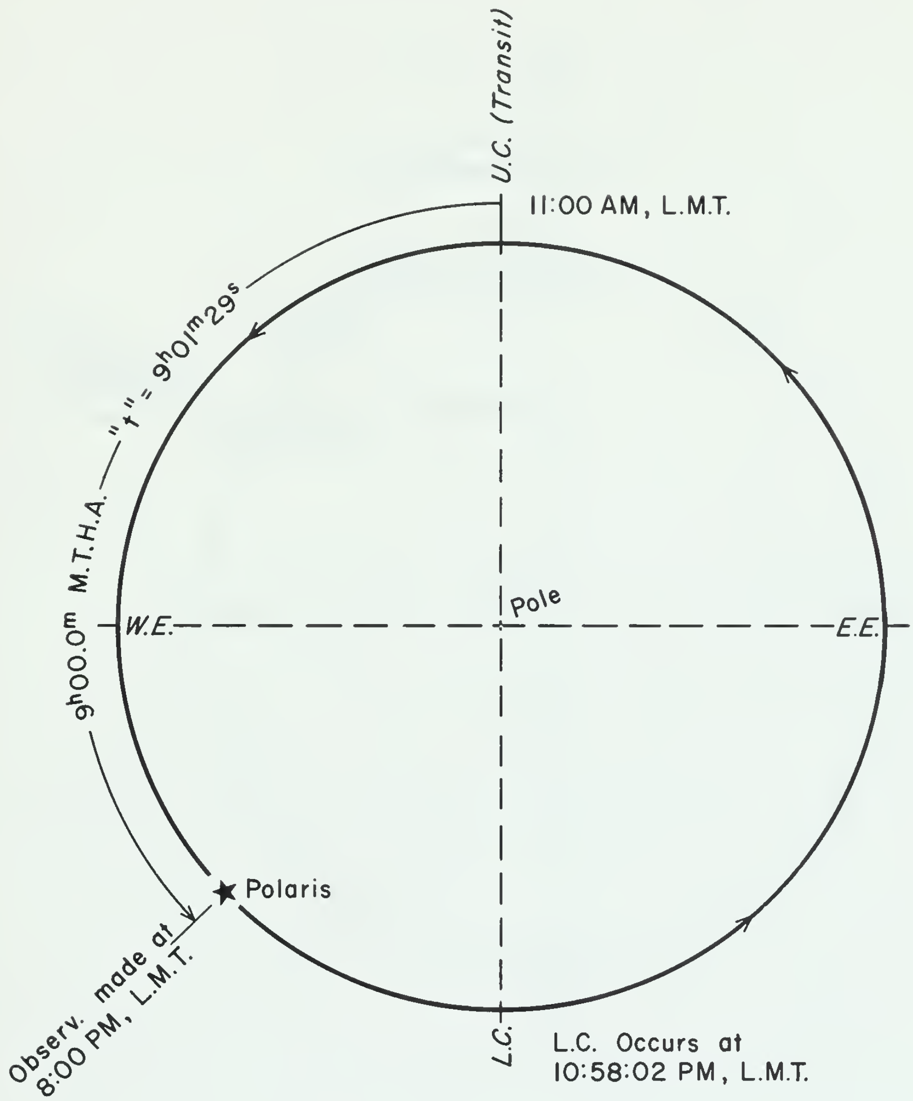

FIG. 11 - HOUR ANGLE OF POLARIS - WEST OF POLE.

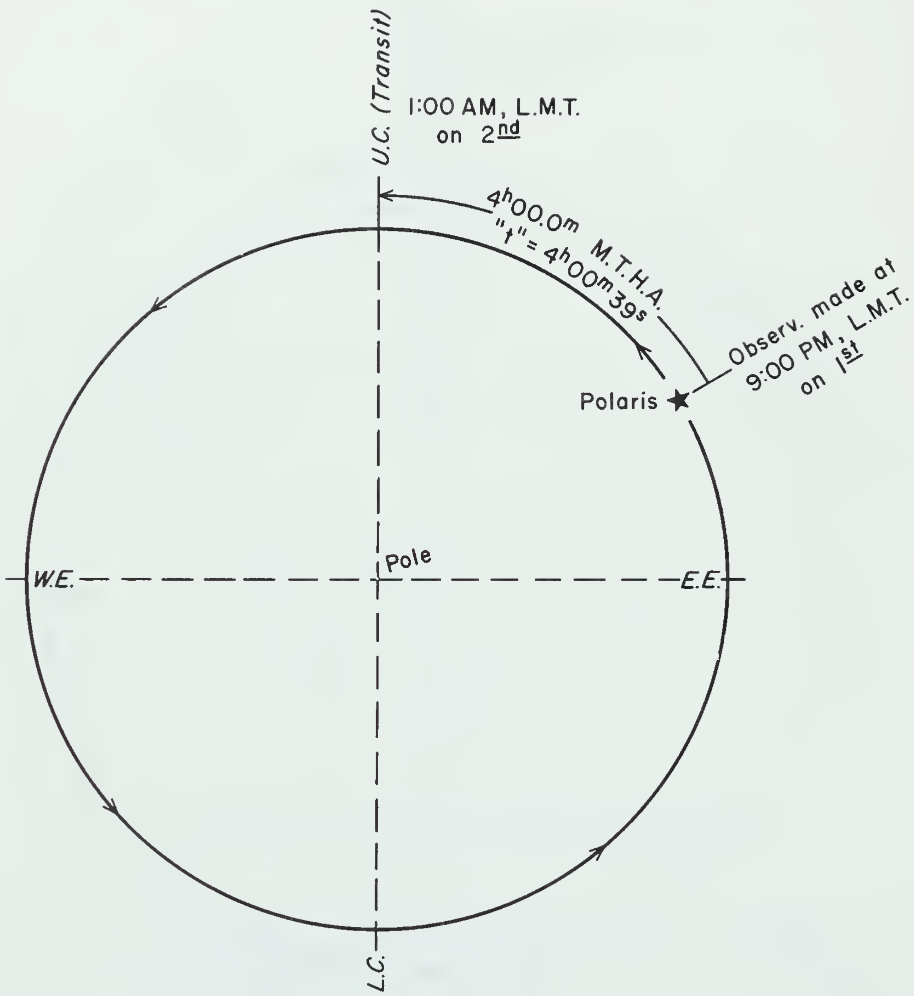

FIG. 12 – HOUR ANGLE OF POLARIS – EAST OF POLE.

SELECTED EXAMPLES

OF

AZIMUTH DETERMINATION

BY

DIRECT OBSERVATION

ON THE

SUN AND STARS

EXAMPLE I - SUN

Explanatory Comments

(Note)

(A) The observing station is 1° 47' in Longitude WEST of the 120th (zone) meridian. 1° 47' in Longitude is 07^m 08^s in MEAN TIME; to be subtracted from Standard Time.

(B) The Equation of Time was interpolated between that listed in the Ephemeris for Mar. 3rd and Mar. 4th, for later use in Example III. The method of interpolation is shown in Example II. For ordinary purposes (if determining Elapsed Time to compute declination) the Equation of Time would NOT need to be interpolated.

(C) The Apparent (TRUE) Time of observation on the REAL sun.

(D) Apparent Noon Greenwich is 12:00:00 hrs. Greenwich Apparent Time. The Apparent Time on the local meridian at the same instant is the difference in longitude converted to time. Since the station is located 8^h 07^m 08^s West of Greenwich the Local Apparent Time at the same instant is 3:52: 52 hrs. (AM)

(E) The watch is set for 8:00 hrs. from Greenwich and will read 4:00 AM when it is noon in Greenwich regardless of what the longitude might be. The important thing is to know what the watch reads when it is noon in Greenwich.

(F) The result is the same because steps (A) and (D) cancel each other. 3:52:52 and 07:08 add up to 4:00:00 hrs.

(G) The total change in declination since noon in Greenwich is based upon the Elapsed Time and change in declination for 1 hr. The change per hour is listed in the Ephemeris for each day at App. Noon Greenwich.

(H) South decl. is DECREASING (see the NEXT tabular value) so the total change in decl. (for elapsed time) is subtracted from the decl. listed in the Ephemeris for Apparent Noon Greenwich.

(I) The refraction in Zenith Distance is listed on page 25 of the Ephemeris. The refraction is to be corrected for temperature and barometric pressure (elevation). The corrected refraction is ALWAYS SUBTRACTED from the observed vertical angle. Parallax is always added. Refraction is difficult (if not impossible) to determine at low vertical angles. For vertical angles above 25° the refraction is (nearly) R = 58" cot V.A.

(J) This formula is used throughout these examples for altitude observaions. The figures in brackets [ ] are products of the functions. The signs (+) and (-) are the algebraic signs. South declination is minus, altitude and Latitude are plus.

(K) Actually the Azimuth is from North in any case. The cosine of 128° 37' 17" is -.62417 because the cosine of angles between 90° and 270° is minus. The absolute value (.62417) of the cosine of 51° 22' 43" is the same as for 128° 37' 17". The smaller angle is then in fact a BEARING of the Sun in relation to either North or South, the algebraic sign denotes which. The time of day determines whether the sun is East or West of the meridian.

EXAMPLE I - SUN

ALTITUDE OBSERVATION ON THE SUN FOR AZIMUTH - SUN SE.

March 3, 1971

Latitude 42° 15' N. Longitude 121° 47' W. ($8^h\ 07^m\ 08^s$)

Temp. 40° Elev. 4300 ft. Horizontal Angle turned left to the Sun from line

	H. A.	V. A.	P. S. T.
1)D	52° 40'	25° 52' 00"	9:17:15
6)R	52° 15'	26° 18' 00"	9:21:11
M)	52° 27' 30"	26° 05' 00"	9:19:13 AM
2)D	52° 36'	25° 57' 30"	
5)R	52° 20'	26° 13' 00"	
M)	52° 28' 00"	26° 05' 15"	
3)D	52° 31'	26° 02' 00"	
4)R	52° 24'	26° 07' 00"	
M)	52° 27' 30"	26° 04' 30"	

Average H. A.	Average V. A.	Average Time
52° 27' 40"	26° 04' 55"	9:19:13AM PST

Determine the elapsed time - between Apparent Noon Greenwich and the Apparent Time of observation, the result to be used in determining the declination of the sun at time of observation (and Eq. of T. if needed).

USING LONGITUDE ((A) (B) etc. denote explanatory comments)

9:19:13	AM PST of observation
- 07:08	difference in time of Long. W. of 120th meridian (A)
9:12:05	Local Mean Time (LMT) of observation
- 12:05	Equation of Time (interpolated from Ephemeris) (B)
9:00:00	Apparent Time of observation (C)
-3:52:52	L.A.T. of Apparent Noon Greenwich (12:00:00 - $8^h\ 07^m\ 08^s$) (D)
5:07:08	Elapsed Time since Apparent Noon Greenwich = 5.12 hrs.

LONGITUDE UNKNOWN

9:19:13	AM PST of observation
-4:00:00	AM PST here when noon in Greenwich (E)
5:19:13	
- 12:05	Equation of Time (interpolated from Ephemeris)
5:07:08	Elapsed Time = 5.12 hrs. (same result without use of longitude) (F)

DECLINATION

Hourly change		Elapsed Time		Total change	
57.42"	X	5.12 hrs.	=	294" = 4' 54"	(G)

Listed decl. = 6° 57' 32" - 4' 54" = 6° 52' 38" S. Decl.(at time of obs.)(H)

REFRACTION AND TRUE ALTITUDE

Refr. in zenith dist.		Elev.		Temp.		Parallax		True correction	
1' 58" = 118"	x	.87	x	1.02	-	08"	=	97" = 1' 37"	(I)

V.A. = 26° 04' 55" - 1' 37" = 26° 03' 18" = true altitude = "h"

FORMULA: $$\text{Cos } A = \frac{\sin \delta - \sin h \sin \phi}{\cos h \cos \phi} = \frac{(-.11974) - \overbrace{(+.43923)\,(+.67237)}^{[+.29533]}}{\underbrace{(+.89837)\,(+.74022)}_{[+.66499]}} \quad \text{(J)}$$

$$\text{Cos } A = \frac{(-.11974) - [+.29533]}{[+.66499]} = \frac{-.41507}{+.66499} = -.62417 = \text{S. } 51° \; 22' \; 43'' \text{ E.}$$

H.A. = 52° 27' 40" - 51° 22' 43" = S. 1° 04' 57" W. = Bearing of line.

Note: If the algebraic sign of Cos A is minus, the azimuth is from South. (K)
If the algebraic sign of Cos A is positive, the azimuth is from North.

EXAMPLE II - SUN

Explanatory Comments

(Note)

(A) The average Standard Time of observation on a 24 hour basis. The same as 4:41:33 PM PST.

(B) The interpolated Equation of Time, see (D) below. The Equation of Time is listed in the Ephemeris as minus. This is minus <u>from Apparent Time</u>, to arrive at Local Mean Time. Since we have LMT and want Apparent Time of observation, the Equation of Time must be added.

(C) This is the same as "LONGITUDE UNKNOWN" in Example I - Sun.

(D) The Equation of Time must be interpolated to the value at the time of observation when computing the Apparent Time Hour Angle of the Sun. In this example the Equation of Time is actually (very nearly) 6.38" less at the time of observation than the value listed for noon Greenwich. For an Altitude observation (only) this interpolation is NOT necessary.

(E) The declination should be computed on the basis of elapsed time from the NEAREST time listed in the Ephemeris. 12.7 hrs. has elapsed since Noon Greenwich on the 11th, with a listed hourly change in declination of 10.85" per hr. This is 11.3 hrs. PRIOR to Noon Greenwich on the 12th, when the hourly change in declination is 9.84". Computing BACK from Noon on the 12th the declination would be 23° 05' 59" N. In this example the 1" difference is insignificant. However, in longitudes further west and/or at later times in the day during periods of greater difference in daily declination, the "spread" could become significant enough to be of some concern. It would all depend upon the accuracy desired.

(F) The example illustrates the need to correct the listed refraction for temperature, elevation, and parallax, which some surveyors tend to ignore. The higher the temperature and elevation above sea level, the greater will be correction to the refraction. The atmosphere is much thinner at high elevations and temperatures.

A sketch should be made when converting the horizontal angle observed and azimuth of the sun to the BEARING of the line to avoid miscalculations. This example could have been computed by saying:

180° - (Az. + H.A.) or:

180° 00' 00" - (79° 23' 54" + 99° 35' 00") = S. 1° 01' 06" W.

It is immaterial which technique is used as long as the final answer is correct.

EXAMPLE II - SUN

ALTITUDE OBSERVATION ON THE SUN FOR AZIMUTH - SUN NW.

June 11, 1971

Latitude 37° 30' N. Longitude 115° 30' W. (7^h 42^m)

Temp. 105° Elev. 3500 ft. Horizontal Angle turned Right to Sun from line.

Average H. A.	Average V. A.	Average Time
99° 35' 00"	25° 21' 00"	16:41:33 PST
	(A)	(24 hr. basis)

Determine elapsed time - between apparent time of observation and apparent noon Greenwich. Result used to determine declination at time of observation.

16: 41: 33 PST of observation
\+ 18: 00 difference in time of Long. E. of 120th Meridian
16: 59: 33 LMT of observation
\+ 0: 27 Equation of Time (interpolated) (B)
17: 00: 00 Apparent Time of observation
-4: 18: 00 Local Apparent Time of apparent noon Greenwich
12: 42: 00 Elapsed Time since noon Greenwich = 12.7 hours

OR 16: 41: 33 PST obs. (C)
-4: 00: 00 PST of noon Gr.
12: 41: 33
\+ 0: 27 Eq. of Time
12: 42: 00 = 12. 7 hours

For an altitude observation the Equation of Time can be taken directly from the Ephemeris for the day. But to determine the HOUR ANGLE of the sun at a given time, the Eq. of Time would have to be interpolated bet. that given for the day and that given for the NEXT day, as in this example:

Eq. of Time - June 11 0^m 33.83^s 12^h 42^m = 762^m
Eq. of Time - June 12 $\bar{0}^m$ 21.75^s (D)
12.08^s diff. 24^h 00^m = 1440^m

Proportion: $\frac{762}{1440} = \frac{X}{12.08}$ X = 6.38^s

33.83 (June 11)
-6.38
27.45^s = Eq. of Time at obs.

DECLINATION

Hourly change		Elapsed time		Total change	
10.85"	x	12.7 hrs.	=	138" = 2' 18"	(E)

Declination 23° 03' 42" + 2' 18" = 23° 06' 00" N. decl. at time of obs.

REFRACTION AND TRUE ALTITUDE

Refr. in zenith dist.		Elev.		Temp.		Parallax		True correction	
2' 01" = 121"	x	.89	x	.91	-	08"	=	90" = 1' 30"	(F)

V. A. = 25° 21' 00" - 1' 30" = 25° 19' 30" = h (true altitude)

FORMULA: $\cos A = \frac{\sin \delta - \sin h \ \sin \phi}{\cos h \ \cos \phi}$

$$\cos A = \frac{(+.39234) - (+.42775)\ (+.60876)}{(+.90390)\ (+.79335)} = \frac{+.13194}{+.71711} = +.18398$$

[+.26040] [+.71711]

A = 79° 23' 54" (and is positive, so azimuth is from N.) = N. 79° 23' 54" W.,

or 100° 36' 06" from South
\- 99° 35' 00" Horiz. angle
S. 1° 01' 06" W., Bearing of line

EXAMPLE III - SUN

Explanatory Comments

(Note)

(A) The values given here are taken directly from "Example I - Sun" to illustrate the comparison between the two methods of computing the azimuth of the sun: Altitude and Hour Angle.

(B) The Equation of Time was interpolated in "Example I - Sun" for later use in computing the Apparent Time Hour Angle, used in this example.

(C) The true Apparent Time of observation. This value is essential in the computations and must be determined accurately.

(D) The sun will always be exactly on the local meridian at 12:00:00 noon Local Apparent Time. No computation is required.

(E) This is the Local Hour Angle measured in APPARENT TIME from the local meridian. This value, once determined, must be converted to degrees (the "t" value) for looking up the trigonometric functions required.

(F) Note that the declination is SOUTH and treated as a MINUS quantity, the "tan δ" is negative in the computations.

(G) Again, a sketch should be made (eliminated in these examples) to facilitate determining the Bearing of the line.

(H) Correct time (to the nearest second) and correct longitude is essential for accurate computation by the Hour Angle formula. By the same token, the vertical angle must be observed accurately using the Altitude formula. At low altitudes the latter is difficult to obtain and refraction is great. A judgment must be made: Which method is most appropriate for the conditions to achieve the best results?

EXAMPLE III - SUN

HOUR ANGLE OBSERVATION ON THE SUN FOR AZIMUTH FROM EXAMPLE I

March 3, 1971

Latitude 42° 15' N. Longitude 121° 47' W. ($8^h\ 07^m\ 08^s$)

Average Horizontal Angle, turned Left to Sun from line = 52° 27' 40"

Averaged P. S. T. of observation = 9: 19: 13 AM (A)

Declination of the Sun at time of observation = 6° 52' 38" S.(from Example I)

HOUR ANGLE COMPUTATION

9:19:13	PST of observation
-7:08	diff. for Long. W. of 120th meridian
9:12:05	LMT of observation
-12:05	Equation of Time (interpolated) (B)
9:00:00	Apparent Time of observation (C)
12:00:00	Apparent Time of Sun on the Meridian (D)
-9:00:00	Apparent Time of Observation
3:00:00	Local Hour Angle at time of observation = "t" = 45° 00' 00" (E)

FORMULA: $\text{Tan } A = \dfrac{\sin t}{\cos \phi \ \tan \delta - \sin \phi \ \cos t}$

ϕ = Latitude
δ = Declination
t = Local Hour Angle

$$\text{Tan } A = \frac{(+.70711)}{\underset{[-.08928]}{(+.74022)\ (-.12061)} - \underset{[+.47544]}{(+.67237)(+.70711)}} \qquad \text{(F)}$$

$$\text{Tan } A = \frac{+.70711}{-.56472} = -1.25214 = 51°\ 23'\ 17'' \text{ or S. } 51°\ 23'\ 17'' \text{ E.}$$

H. A. = 52° 27' 40"
-51° 23' 17"
S.1° 04' 23" W., Bearing of line (G)

The same rule applies as with the Cos A formula. If the sign of the Tan A is minus, the bearing is from South. If positive, the bearing is from North.

(The spread of 0° 00' 34" bet. the above azimuth and that arrived at in Example I by the altitude solution can be caused by: (a) Error in observed vertical angle, (b) error in watch time of observation, (c) or any combination thereof.) (H)

EXAMPLE IV - SUN

HOUR ANGLE OBSERVATION ON THE SUN FOR AZIMUTH FROM EXAMPLE II

June 11, 1971

Latitude 37° 30' N. Longitude 115° 30' W. (7^h 42^m)

Horizontal Angle turned Right to Sun from line, Average = 99° 35' 00"

Averaged P.S.T. of observation = 16:41:33 hrs.

Declination of Sun at time of observation = 23° 05' 59" (from Example II)

HOUR ANGLE COMPUTATION

16: 41: 33	Correct PST of observation
+ 18: 00	Diff. in time of Long. E. of 120th Meridian
16: 59: 33	LMT of observation
+ 0: 27	Equation of Time (interpolated, see Example II)
17: 00: 00	Apparent Time of observation
-12: 00: 00	Apparent Noon, Sun on the Meridian
5: 00: 00	Local Hour Angle (in Apparent Time) = t = 75° 00' 00"

FORMULA: $$\text{Tan } A = \frac{\sin t}{\cos\phi \ \tan\delta - \sin\phi \ \cos t}$$

ϕ = Latitude
δ = Declination
t = LHA

$$\text{Tan } A = \frac{(+.96593)}{\underbrace{(+.79335)\ (+.42654)}_{[+.33840]} - \underbrace{(+.60876)\ (+.25882)}_{[+.15756]}} = \frac{+.96593}{+.18084}$$

Tan A = + 5.34135 = N. 79° 23' 49" W. (or) 100° 36' 11" Az. from South
- 99° 35' 00" Horiz. Angle
S. 1° 01' 11" W. Bearing of Line

No explanatory comments appear necessary. The procedure and method of computation is the same as that of "Example III - Sun", except in the time and azimuth.

EXAMPLE V - SUN

Explanatory Comments

(Note)

(see facing page)

(A) Since we have LMT and require Standard Time the difference in Longitude is <u>added</u>.

(B) This is NOT EXACT because the Equation of Time was not interpolated. However, the result is close enough for this purpose.

(C) These formule are written treating the declination as an absolute value. The sign of the declination (plus or minus) is then "taken care of" in the statements.

(D) The U.S.G.S. quadrangle maps are made on Geodetic Latitude. The Astronomic Latitude, as determined here, could vary considerably (up to about 30") from Geodetic Latitude. For ordinary work by BLM surveyors running transit lines, this difference is usually ignored. When stating the Latitude and Longitude of a point in the field notes or on a plat, the <u>Method</u> of determining the geographic position should always be stated also.

EXAMPLE V - SUN

ALTITUDE OBSERVATION ON THE SUN FOR LATITUDE, MERIDIAN PASSAGE

September 25, 1971

(Approx.) Latitude 48° 10' N. (Approx.) Longitude 109° 10' W.(7^h 16^m 40^s)

Temp. 70° Elev. 2500 ft.

COMPUTE WATCH TIME OF MERIDIAN PASSAGE (Watch set for accurate MST)

12: 00: 00	Apparent Time of meridian passage (transit)
- 08: 08	Equation of Time (from Ephemeris)
11: 51: 52	LMT of Sun's transit
+ 16: 40	Diff. in Long. W. of 105th meridian (A)
12: 08: 32	PM MST of Sun on the meridian (B)

Mean Vertical Angle observed by a series of observations on the sun at an average time of 12: 08 PM MST :
41° 02' 30"

COMPUTE TRUE ALTITIDE

Refr. in Zenith Dist.		Elev.		Temp.		Parallax	
67"	x	.93	x	.96	—	07"	= 0' 53" (corr. refr.)

V. A. = 41° 02' 30"
- 0' 53"
41° 01' 37" = h

DECLINATION

7^h 16^m 40^s or 7.28 hrs. has elapsed since it was Apparent Noon in Greenwich

Hourly change		Elapsed time		Total change
58.45"	x	7.28	=	426" = 7' 06"

Decl. for Noon Greenwich = 0° 42' 01" (from Ephemeris)
+ 7' 06"
0° 49' 07" South decl. at time of observation

FORMULAE:

$\phi = 90° + \delta - h$ (for NORTH Declinations)

$\phi = 90° - \delta - h$ (for SOUTH Declinations)

(C)

90° 00' 00"
- 49' 07" decl.
89° 10' 53"
-41° 01' 37" h
48° 09' 16" = True Latitude (D)

(Determination of Latitude with the ordinary one minute transit is probably NOT as accurate as scaling the Latitude from a Geological Survey quadrangle map, if one is available. The Latitude can be determined about as accurately as scaling, if a one second reading theodolite (T-2) is used and careful observations are made)

EXAMPLE I - POLARIS

Explanatory Comments

(Note)

(A) The watch should be as correct as possible. In using the tables in the Ephemeris, if the watch error is less than one minute there will be only slight error in the calculated azimuth of Polaris.

(B) The difference in longitudinal arc converted to mean time.

(C) Convert to 24 hr. clock because by inspection it is already known that U.C. will (does) occur in the AM.

(D) The Ephemeris tables do not exceed $11^h\ 58^m$ of M.T.H.A. Therefore, the MTHA of Polaris must be computed in time PRIOR to the following U.C. of Polaris.

(E) The sidereal conversion is taken from the table on page 27 of the Ephemeris in amount for either longitude or time. It may also be computed on a direct proportion of $3^m\ 56^s$:

$$121.45° / 360° \text{ of } 236^s = 1^m\ 20^s$$

(F) The time counted from $0^h\ 00^m$ on Sept. 15th, which places the time of U.C. on the same basis as the time of observation (for easy subtraction purposes) to determine the MTHA.

(G) The MTHA is readily determined <u>prior</u> to U.C.

(H) The MTHA of Polaris is the same as is tabulated on page 19 of the Ephemeris for a declination of 89° 08' 10". Interpolation is required in THIS example only for Latitude of the observing station. The correction for declination is taken from the column headed "CORR. TO AZIMUTH", Add for Decl. 89° 08' 00". The .2 minute correction is caused by the difference of 11" in declination, the tangent of the declination being an integral function in the "t" angle formula. The azimuth of Polaris in the Ephemeris is actually computed on even periods of Sidereal Time and then listed for equivalent Mean Time Hour Angles.

EXAMPLE I - POLARIS

HOUR ANGLE OBSERVATION ON POLARIS FOR AZIMUTH

STAR EAST OF MERIDIAN

September 15, 1971 Average time - 6:13:50 PM PST

Latitude 38° 30' N. Longitude 121° 27' W. (8^h 05^m 48^s)

Declination of Polaris 89° 07' 59" N.

COMPUTATION OF HOUR ANGLE

(A)	Correct 120th Meridian time of observation	6:13:50 PM
(B)	Minus difference in longitude W. of 120th meridian . .	- 5:48
	LOCAL MEAN TIME (LMT) of observation	6:08:02
(C)	Convert to 24 hour clock	+ 12:00:00
		18:08:02 hrs.
(D)	Greenwich Mean Time of Upper Culmination of Polaris September 16th (from Ephemeris)	2:28:00 AM
(E)	Minus sidereal conversion for 121° 27' W. Long. . . .	- 1:20
	Local Mean Time of U.C., Sept. 16th	2:26:40
(F)	Plus 24 hrs. to get on the same basis (Sept. 15th). .	+ 24:00:00
	Time of U.C. from 0^h on Sept. 15th	26:26:40 (AM)

The Mean Time Hour Angle is the difference in Mean Time between LMT of observation and LMT of U.C. Therefore:

	26:26:40	LMT of U.C.
	- 18:08:02	LMT of observ.
(G)	8:18:38	(or) 8^h 18.6^m = (local) MEAN TIME HOUR ANGLE (MTHA)

The tables in the BLM Ephemeris for "Azimuths of Polaris at all Hour Angles" are listed for MEAN TIME at about 10 minute intervals and every 2° of Latitude for a given declination of Polaris. The tables must be interpolated for other than the listed Hour Angles, Latitudes and Declination. The most expedient method of interpolating is by the following form:

	MEAN TIME HOUR ANGLE	LATITUDE			Correction for Declination
		38°	38° 30'	40°	89° 07' 59"
(H)	8^h 18.6^m	53.5'	53.9'	55.0'	+ 0.2'

The Azimuth of Polaris for Latitude 38° 30' and Declination 89° 08' 10" is 0° 53.9', with a correction for declination 89° 07' 59" of 0.2' additive.

Add the two quantities: 53.9' + 0.2' = 0° 54.1' = Azimuth of Polaris.

Polaris is 8^h 18.6^m in MTHA Prior to the succeeding time of Upper Culmination and is therefore EAST of the Pole, and the Bearing of the star at the time of observation is:

N. 0° 54' 06" E.

EXAMPLE II - POLARIS

Explanatory Comments

(Note)

(A) The sidereal conversion is always minus in West Longitude from Greenwich in determining the Local Mean Time of transit (culmination) of the star. In this example longitude is expressed in hours and minutes of time.

(B) No conversion to a 24 hr. clock is required since the LMT of U. C. and LMT of observation both occur in the P.M. of the same day.

(C) The MTHA falls <u>between</u> those listed in the Ephemeris on page 18. Interpolation must be made for both an intermediate MTHA and Latitude. The correction for declination is Minus because the declination of 89° 08' 16" exceeds the declination on which the tables are based.

(D) The tables are in tenths of a minute. Conversion to seconds is usually made at the end of the computations. If greater precision is required an Ephemeris listed in seconds would be required and computations made using the formula. In BLM practice and using ordinary transits the tables in the Ephemeris are adequate.

EXAMPLE II - POLARIS

HOUR ANGLE OBSERVATION ON POLARIS FOR AZIMUTH

STAR WEST OF THE MERIDIAN

March 5, 1971 — Average Time 5:50:00 PM MST

Latitude 33° 30' N. — Longitude 111° 50' W. ($7^h\ 27^m\ 20^s$)

Declination of Polaris 89° 08' 16" N.

COMPUTATION OF HOUR ANGLE

	Correct 105th Meridian Time of observation	5:50:00 PM MST
(A)	Minus difference in long. W. of 105th meridian	- 27:20
	Local Mean Time of observation	5:22:40 PM
	Greenwich Mean Time of Upper Culmination, March 5th	3:12:12 PM
	Minus sidereal conversion for $7^h\ 27^m$ longitude	- 1:13
	Local Mean Time of Upper Culmination, March 5th . . .	3:10:59 PM

The MEAN TIME Hour Angle is the difference between Local Mean Time of observation and Local Mean Time of Upper Culmination. Therefore:

(B)

- 5:22:40 PM LMT of observ.
3:10:59 PM LMT of U.C.
2:11:41 = MTHA (or) $2^h\ 11.7^m$

Interpolate the tables of Azimuths of Polaris at all Hour Angles listed in the Ephemeris on page 18:

(C)

MEAN TIME HOUR ANGLE	LATITUDE			Correction for Declination
	32°	33° 30'	34°	89° 08' 16"
$2^h\ 09.6^m$	33.1'		33.9'	-0.1'
$2^h\ 11.7^m$	33.6'	34.2'	34.4'	-0.1'
$2^h\ 19.6^m$	35.3'		36.2'	-0.1'

(D) The Azimuth of Polaris at Latitude 33° 30' N., $2^h\ 11.7^m$ of MTHA, and Declination 89° 08' 10" is 0° 34.2'. The correction for Declination 89° 08' 16" is 0° 0.1' subractive. Therefore the Azimuth of Polaris at the time of observation is: 0° 34.2' - 0° 0.1' = 0° 34' 06".

The observation was made $2^h\ 11.7^m$ AFTER Upper Culmination so the Star is WEST of the Meridian and the Bearing of the Star at the time of observation is:

N. 0° 34' 06" W.

EXAMPLE III - POLARIS

Explanatory Comments

(Note)

(A) Conversion to 24 hr. clock is made to get both the LMT of observation and U. C. on the same term or "common denominator."

(B) The amount of sidereal conversion is based on the amount of MTHA. The sidereal conversion is ADDED to MTHA to arrive at the Sidereal Time Interval, the amount of SIDEREAL TIME that has elapsed since Upper Culmination.

(C) The sidereal time interval is converted to arc, the value of "t" in the formula. In this example, the Azimuth of Polaris will be computed in lieu of the tables in the Ephemeris.

(D) Note that there is NO parallax correction on a star. The parallax is too small to measure with surveying instruments.

(E) The tables on page 23 of the Ephemeris are used in this example to determine Latitude from the observed vertical angle of Polaris. A double interpolation is required for an intermediate MTHA and Declination.

(F) The Astronomic Latitude as computed from this observation. Since only a one minute transit was used, the Latitude would be more accurately scaled from a quadrangle map, if available.

(G) The "Tan A" will always be plus on Polaris. The time of observation determines whether East or West of the pole. The trig. functions used in these examples are from 8 place tables rounded off to 5 decimal places. In this example the "tan δ" must be determined accurately.

EXAMPLE III - POLARIS

HOUR ANGLE OBSERVATION ON POLARIS FOR AZIMUTH AND LATITUDE, STAR WEST OF MERIDIAN

May 15, 1971 Latitude 40° 22' N.(approx.) Longitude 117° 20' W. (7^h 49^m 20^s)

Declination 89° 07' 56" Elev. 6900 ft. Temp. 80° Horiz. Angle turned LEFT to Star

	H. A.	V. A.	P.S.T.
1)D	0° 41' 00"	39° 45' 00"	7: 30: 00 PM
2)R	0° 41' 00"	39° 44' 30"	7: 31: 00
3)R	0° 40' 30"	39° 44' 30"	7: 31: 30
4)D	0° 40' 30"	39° 44' 00"	7: 32: 30
m)	0° 40' 45"	39° 44' 30"	7: 31: 30

COMPUTATION OF HOUR ANGLES

PST of observation	7:31:30
Diff. of Long. E. of 120th Mer.	+ 10:40
LMT of obs.	7:42:10
Convert to 24 hr. clock	+12:00:00
(A)	19:42:10

GMT of U. C. of Polaris	10:32:48 AM
Minus sid. conv. (7^h 50^m)	- 1:17
LMT of U. C., May 15th	10:31:31 AM

19:42:10 LMT of obs.
-10:31:31 LMT of U. C.
9:10:39 = MEAN TIME HOUR ANGLE
+ 1:30 = Sidereal corr. for Hour Angle (B)
$9^h 12^m 09^s$= Sidereal Time Interval = "t" (C)

CONVERT "t" to Degrees
9^h = 135° 00'
12^m = 3° 00'
09^s = 2' 15"
138° 02' 15" = t

CORRECTION OF OBSERVED VERTICAL ANGLE

Refr. in zenith dist.		Elev.		Temp.		Corr. ref.	
70"	x	.79	x	.94	=	52"	(D)

V. A. = 39° 44' 30" - 52" = 39° 43' 38" = h

PRIMARY ADJUSTMENT TO ELEVATION OF POLE (E)

MEAN TIME HOUR ANGLE	DECLINATION		
	89° 07' 40"	89° 07' 56"	89° 08' 00"
9^h 10.5^m	39' 04"	38' 52"	38' 49"
9^h 10.7^m		38' 53"	
9^h 22.5^m	40' 50"	40' 37"	40' 34"

0° 38' 53"
- 02"= suppl. corr.
0° 38' 51"= primary adj. (ADD, Polaris below pole)

39° 43' 38" = h
+ 38' 51" = prim. adj.
40° 22' 29" = True Latitude (F)

COMPUTATION OF AZIMUTH BY FORMULA

FORMULA: $\text{Tan } A = \dfrac{\sin t}{\cos \phi \ \tan \delta - \sin \phi \ \cos t}$

t = SIDEREAL HOUR ANGLE
ϕ = Latitude
δ = Declination

$$\text{Tan } A = \frac{+.66864}{\underset{[+50.29598]}{(+.76182)\,(+66.02082)} - \underset{[-.48168]}{(+.64778)\,(-.74358)}} = \frac{+.66864}{+50.77766} = +.01317 \quad (G)$$

Tan A = .01317 = N. 0° 45' 16" W. = Azimuth of Polaris
- 0° 40' 45" = Horiz. angle turned to star (left)
N. 0° 04' 31" W. = Bearing of Line

EXAMPLE IV - POLARIS

Explanatory Comments

(Note)

(A) The Greenwich Mean Time (GMT) of Western Elongation (W.E.). The mean Time of Elongation at Greenwich is listed in the Ephemeris only for Latitude 40°. (Ephemeris page 3)

(B) The Local Mean Time of W.E., if the station was located in Latitude 40°.

(C) The correction to the time of Elongation for Latitude 42° 30' N., taken from Ephemeris page 22, column 2, interpolated. Note the plus and minus signs. These indicate the direction to apply the listed amount of time for the Latitude of the station to arrive at the LMT of Elongation at the station of observation.

(D) The correction is ADDED here because the conversion is from Local Mean Time TO Standard Time.

(E) The correct M.S.T. of W.E., since the watch is set for standard time. The observation should be made during the period from 5 minutes before to 5 minutes after the time of Elongation when no departure in azimuth could be detected with a transit.

(F) Interpolation of the tables on Ephemeris page 22. The method is similar to interpolation of the hour angle tables. The interpolation is for the differences in Latitude and DECLINATION.

(G) The formula is simple and easily computed on a calculator. Eight place tables should be employed for best results.

EXAMPLE IV - POLARIS

AZIMUTH OF POLARIS AT ELONGATION

April 15, 1971

Latitude 42° 30' N. Longitude 116° 30' W. (7^h 46^m)

Declination of Polaris 89° 08' 05"

COMPUTATION OF TIME OF ELONGATION

(A)	GMT of W.E. of Polaris, Lat. 40°, April 15th	6:26:42 PM
	Sidereal conversion for long. 116° 30'	- 1:16
(B)	LMT of W.E., Lat 40°	6:25:26
(C)	Correction to time of Elongation, Lat. 42° 30'	- 0:15
	Local Mean Time of W.E., April 15th, Lat. 42° 30' . .	6:25:11
(D)	Conv. to Standard Time for long. 116° 30'.	+ 46:00
(E)	Mountain Standard Time of Western Elongation	7:01:11 PM

INTERPOLATION OF TABLES OF AZIMUTHS OF POLARIS AT ELONGATION

(F)

LATITUDE	DECLINATION 89°		
	08' 00"	08' 05"	08' 10"
42°	1° 09' 59"	1° 09' 52"	1° 09' 45"
42° 30'		1° 10' 26"	
43°	1 ° 11' 06"	1° 11' 00"	1° 10' 53"

Azimuth of Polaris = N. 1° 10' 26" W.

Another easy way to arrive at the Azimuth of Polaris at Elongation is by use of the

FORMULA: $\text{Sin A} = \dfrac{\text{Cos } \delta}{\text{Cos } \phi}$

δ = Declination
ϕ = Latitude

(G) $\text{Sin A} = \dfrac{.01510137}{.73727734} = .0204826$ = N. 1° 10' 25" W.

EXAMPLE V - POLARIS

Explanatory Comments

(Note)

(A) The Greenwich MEAN TIME of Upper Culmination of Polaris is listed for each day and taken directly from the Ephemeris.

(B) Upper Culmination occurred in the morning and it was desired to make the observation for Latitude in the evening near sunset. Lower Culmination will always occur 11^h 58^m 02^s in Mean Time (12^h Sidereal Time) AFTER Upper Culmination.

(C) The correction for Longitude is subtracted - the station being EAST of the Zone Meridian. The correction here is to change Local Mean Time TO Standard Time.

(D) The instant in Standard Time that the star will be due North, on the meridian. Observation can be made during the period from 5 minutes prior to, until 5 minutes following Culmination, with no measureable change in vertical angle to the star.

(E) The refraction should be carefully corrected for temperature and elevation. Again note, there is NO parallax correction.

(F) The astronomic Latitude. Observation at Culmination with a theodolite should yield good results.

EXAMPLE V - POLARIS

LATITUDE OBSERVATION ON POLARIS AT CULMINATION

June 27, 1971

Latitude 41° 10' N. (approx.) Longitude 104° 30' W. (6^h 58^m)

Temp. 65° Elev. 4500 ft.

Declination of Polaris 89° 07' 49" (Polar Distance = 0° 52' 11")

Mean observed Vertical Angle to Polaris = 40° 19' 00"

COMPUTATION OF TIME OF CULMINATION

(A)	Greenwich Upper Culmination of Polaris, June 27th . . .	7:44:36 AM
	Minus sidereal conversion for Long. 104° 30'	- 1:09
	Local Mean Time of Upper Culmination	7:43:27 AM
(B)	Correction to time of Lower Culmination	+ 11:58:02
	Local Mean Time of Lower Culmination	19:41:29 (PM)
(C)	Correction to LMT for Long. E. of 105th meridian . . .	- 02:00
(D)	Standard Time of Lower Culmination	19:39:29 MST

Polaris is due North, on the meridian, at 7:39:29 PM MST.

REFRACTION AND TRUE ALTITUDE

	Refr. in zenith dist.		Temp.		Elev.		Corr. Refr.
(E)	69"	x	.97	x	.86	=	58"

	Observed V. A. =	40° 19' 00"	
		- 0° 00' 58"	
		40° 18' 02"	= h (True Altitude)
		+ 0° 52' 11"	= Polar Distance (90° - decl.)
(F)		41° 10' 13"	= True Latitude

If Polaris is observed at Upper Culmination the Polar Distance would be subtracted from the True Altitude.

Polaris at Upper or Lower Culmination is by far the most accurate means of determining Latitude. The amount to be added to, or subtracted from, the True Altitude is always the Polar Distance, 90° minus the declination. The declination of Polaris is listed in the Ephemeris to the nearest hundredth of a second, which is probably more accurate than can be observed with most surveying instruments! The only drawback is that Culmination usually occurs at rather inconvenient times of the day.

EXAMPLE I - EQUATORIAL STAR

Explanatory Comments

(Note)

(A) The star selected must be visible above the horizon. Selection can best be made by use of the "Star Finder."

(B) GMT of transit from Ephemeris page 11, column 3.

(C) Amount is listed for the day of observation, Ephemeris page 11, line 10, columns 11 and 12.

(D) The GMT of transit on the day of observation.

(E) Sidereal conversion for longitude in decimal amount. Since the computations are for the position of the star, for identification, decimals of a minute are close enough.

(F) Conversion to Standard Time of transit was used for easy computation of hour angle.

(G) This time was selected because it was near sunset.

(H) The Local Hour Angle in Sidereal Time is required in the "sin h" formula.

(I) Sin h should always be positive. If it turns out negative, the star is below the horizon.

(J) The Tan A ("t" angle) formula may be employed in place of the Cos A formula. It's a matter of personal preference.

(K) Star observations are usually employed for "one evening" refinement of a line, a previous value of azimuth already being known. With practice and familiarity with the stars, it is possible to take several observations, all on different stars, including Polaris, in a short period of time.

EXAMPLE I - EQUATORIAL STAR

COMPUTATION OF ALTITUDE AND AZIMUTH OF A STAR FOR IDENTIFICATION

March 10, 1971 — 6:30 PM PST (anticipated time of observation)

Latitude 42° 15' N. — Longitude 121° 47' W. ($8^h\ 07^m\ 08^s$)

(A) Selected Star: No. 15, alpha Leonis - REGULUS - Decl. + 12° 06' 24"

COMPUTATION OF SIDEREAL HOUR ANGLE

(B)	Star transits at Greenwich, March 1st	11:30.4	PM GMT
(C)	Sidereal reduction to March 10th	− 35.4	
(D)	Star transits at Greenwich, March 10th	10:55.0	PM GMT
(E)	Sidereal conversion for Long. 121° 47' W.	− 1.3	
	Local Mean Time of transit, March 10th	10:53.7	PM LMT
	Correction for Long. to Standard Time	+ 7.1	
(F)	Pacific Standard Time of transit	11:00.8	PM PST
(G)	Anticipated time of observation	− 6:30.0	PM PST
	Mean Time Hour Angle	4:30.8	MTHA
	Sidereal Time correction for Hour Angle	+ 0.7	
(H)	SIDEREAL TIME HOUR ANGLE	$4^h 31.5^m$	= t

Convert "t" to degrees:

$$4^h\ 31^m = 67°\ 45'$$
$$30^s = 7'\ 30''$$
$$67°\ 52'\ 30'' = t$$

h = Altitude of star
t = Sidereal Hour Angle
ϕ = Latitude of station
δ = Declination of star
A = Azimuth of star

(I)

FORMULA:

$$\sin h = \cos t \cos\phi \cos\delta + \sin\phi \sin\delta$$

$$\sin h = \underbrace{(+.37663)(+.74022)(+.97776)}_{[+.27259]} + \underbrace{(+.67237)(+.20973)}_{[+.14102]}$$

$$[+.27259] + [+.14102] = +.41361 = 24°\ 25'\ 55'' = h$$

(J) FORMULA:

$$\cos A = \frac{\sin\delta - \sin h \sin\phi}{\cos h \cos\phi}$$

$$\cos A = \frac{(+.20973) - \overbrace{(+.41361)(+.67237)}^{[+.27810]}}{\underbrace{(+.91045)(+.74022)}_{[+.67393]}} = \frac{[-.06837]}{[+.67393]} = -.10145$$

Cos A = -.10145 = 84° 10' 38" (minus)

Cos A is minus so the bearing (azimuth) of the star is S. 84° 10' 38" E. at an Altitude of 24° 25' 55" at 6:30 PM PST on March 10th.

(K) Turn the horizontal angle to the star from some known point of azimuth, (compass, previous solar shot, etc.) and set the vertical circle at about 24° 28' (24° 26' + 0° 02' refr.). The star should appear very near the center of the field of the telescope. Then proceed to make the observations for azimuth in the normal manner, either by altitude observation or by "time" observation.

EXAMPLE II - EQUATORIAL STAR

Explanatory Comments

(Note)

(A) The anticipated time of observation is arbitrary. The time selected here is at (or near) sunset. The star is not yet visible to the naked eye.

(B) POLLUX is selected because it is the star NEAREST to Prime Vertical (due West) that is high enough at this time to be observed for altitude with good vertical angle position.

(C) GMT of transit, taken from Ephemeris page 12, column 5.

(D) The amount of correction is taken from Ephemeris page 12, line 27, columns 11 and 12.

(E) Conversion of LMT to Standard Time of transit is made because the anticipated time of observation is given in Standard Time.

(F) The formulae employed are applicable for ANY star but are quite inaccurate for Polaris, or other close circumpolar star. The formulae can, therefore, be used for any star listed in the Ephemeris except Polaris, which is easily located by use of the tables of Polaris.

(NOTE) This example and "Example I" on page 43 are for stars with North (+) declinations. On stars with South declinations the "cos δ" is algebraically plus and "sin δ" is minus.

EXAMPLE II - EQUATORIAL STAR

COMPUTATION OF ALTITUDE AND AZIMUTH OF A STAR FOR IDENTIFICATION

May 28, 1971

Latitude 33° 30' N. Longitude 112° 10' W. ($7^h\ 28^m\ 40^s$)

(A) 7:46 PM M.S.T. (anticipated time of observation)

(B) Selected Star - No. 13, beta Gemini - POLLUX Decl. + 28° 05' 54"

COMPUTATION OF SIDEREAL HOUR ANGLE

(C)	Star transits at Greenwich, May 16th	4:08.7 PM GMT
(D)	Sidereal reduction to May 27th	− 43.2
	Star transits at Greenwich, May 27th	3:25.5 PM GMT
	Sidereal conversion for $7^h\ 29^m$ Long.	− 1.2
	Local Mean Time of transit, May 27th	3:24.3 PM LMT
	Correction for Long. to Standard Time	+ 28.7
(E)	MOUNTAIN STANDARD TIME of transit	3:53.0 PM MST
	Anticipated time of observation	− 7:46.0 PM MST
	MEAN TIME Hour Angle	3:53.0 MTHA
	Sidereal correction for Hour Angle	+ 0.7
	SIDEREAL TIME HOUR ANGLE	3:53.7 = t

Convert "t" to degrees: $3^h\ 53^m$ = 58° 15'
42^s = 10' 30"
58° 25' 30" = t

FORMULA: $\sin h = \cos t \cos\phi \cos\delta + \sin\phi \sin\delta$ (NOTE)

$$\sin h = \underbrace{(+.52361)(+.83389)(+.88214)}_{[+.38517]} + \underbrace{(+.55194)(+.47099)}_{[+.25996]}$$

$$\sin h = [+.38517] + [+.25996] = +.64513 = 40°\ 10'\ 32'' = h$$

FORMULA: $$\cos A = \frac{\sin\delta - \sin h \sin\phi}{\cos h \cos\phi}$$

(F) $$\cos A = \frac{(+.47099) - \overbrace{(+.64513)(+.55194)}^{[+.35607]}}{\underbrace{(+.76407)(+.83389)}_{[+.63715]}} = \frac{[+.11492]}{[+.63715]} = +.18037$$

A = 79° 36' 32"

The Cos A is plus so the bearing is from NORTH and the star bears

N. 79° 36' 32" W., at an altitude of 40° 10' 32" (at 7:46 PM MST)

EXAMPLE III - EQUATORIAL STAR

Explanatory Comments

(Note)

(A) The "sets" of observations of horizontal and vertical angles and times of observation are examples of what may reasonably be expected during an actual observation. Each "set" is not necessarily valid IN ITSELF. The better method would be to mean (1) and (2) and mean (3) and (4), then compute the azimuth of the star based on the mean of each set. The result would be four different answers (at least slightly different) and any "bad" set would become immediately apparent. All sets were lumped together in this example in the interest of brevity.

(B) The computations are the same as those employed in Examples I and II - Equatorial Star. The "changeover" to seconds instead of decimals of a minute can be made whenever appropriate.

(C) The azimuth of the star is computed by both formulae as a check. The results should be very nearly the same if the instrument was carefully leveled, the vertical angle carefully measured, and the instant of "pointing" carefully timed. If the resulting azimuths are "spread" by more than 30" of arc, it would be prudent to make further observations. As a general statement, the vertical angle is more likely to be in error than time if equal care is taken in the determination of each. In this example, the star is low in altitude and dropping fast. At this position it would require a 4 second error in time to make a one minute error in azimuth.

EXAMPLE III - EQUATORIAL STAR

HOUR ANGLE OBSERVATION FOR AZIMUTH

September 20, 1971

Latitude 64° 30' N. Longitude 146° 30' W. ($9^h\ 46^m$)

Selected Star: No. 19, alpha Bootis - ARCTURUS - Mag. 0.2, Decl. 19° 19' 48" N.

H. A. turned Right to star from line. Temp. 40° Elev. 800 ft.

	H. A.	V. A.	Alaska S. T.
(A)	1)D 89° 01' 00"	20° 54' 30"	7: 29: 30 PM
	2)R 89° 01' 30"	20° 52' 30"	7: 30: 10
	3)R 89° 02' 00"	20° 51' 30"	7: 30: 42
	4)D 89° 02' 30"	20° 49' 30"	7: 31: 30
	M)89° 01' 45"	20° 52' 00"	7: 30: 28 PM AST

COMPUTATION OF SIDEREAL HOUR ANGLE (B)

Arcturus transits at Greenwich, September 16th	2:34.8	PM GMT
Sidereal correction to September 20th	- 15.7	
Arcturus transits at Greenwich, September 20th	2:19.1	PM GMT
Sidereal conversion for $9^h\ 46^m$ of Long.	- 1.6	
Star transits local meridian on September 20th	2:17.5	PM LMT
Correction for Long. E. of 150th meridian	- 14.0	
Standard Time of transit on the local meridian	- 2:03:30	PM AST
Standard Time of observation	7:30:28	PM AST
Mean Time Hour Angle	5:26:58	
Sidereal conversion for Hour Angle	+ 0:54	
Sidereal Hour Angle at time of observation	5:27:52	= "t"

Convert "t" to degrees $5^h\ 27^m$ = 81° 45'
 52^s = 13'
 81° 58' 00" = t

FORMULA: $$\text{Tan } A = \frac{\sin t}{\cos \phi \tan \delta - \sin \phi \cos t}$$

$$\text{Tan } A = \frac{(+.99019)}{(+.43051)\ (+.35078) - (+.90259)\ (+.13975)} = \frac{(+.99019)}{(+.15101) - (+.12614)}$$

$$\text{Tan } A = \frac{+.99019}{+.02487} = +\ 39.81464 = 88°\ 33'\ 40''$$

Arcturus bears N. 88° 33' 40" W. Line bears S. 2° 24' 35" W.

(C) USE OBSERVED VERTICAL ANGLE FOR A CHECK

Refr.		Temp.		Elev.		Corr. Refr.
150"	x	1.02	x	.98	=	150" = 2' 30"

V. A. = 20° 52' 00" - 2' 30" = 20° 49' 30" = h

$$\text{Cos } A = \frac{\sin \delta - \sin h \sin \phi}{\cos h \cos \phi} = \frac{(+.33101) - \overbrace{(+.35551)\ (+.90259)}^{[+.32088]}}{\underbrace{(+.93467)\ (+.43051)}_{[+.40238]}} = \frac{[+.01013]}{[+.40238]}$$

Cos A = +.02518 = 88° 33' 26" and Azimuth is N. 88° 33' 26" W. (check)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

EPHEMERIS OF THE SUN, POLARIS
AND
OTHER SELECTED STARS
WITH COMPANION DATA AND TABLES

FOR THE YEAR
1971

A Supplement to the Manual of Instruction for the Survey of the Public Lands of the United States

SIXTY-SECOND EDITION

Prepared by Nautical Almanac Office
United States Naval Observatory

UNITED STATES
GOVERNMENT PRINTING OFFICE
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Washington, D.C. 20402 - Price 35 cents

PREFACE

The arrangement of the astronomical data herein conforms to the methods and examples for the determination of time, latitude, and azimuth, practiced by the cadastral engineers of the Bureau of Land Management. These practices are described in the Manual of Instructions for the Survey of the Public Lands of the United States.

The methods long in use have been developed for the best operation of the improved solar transit, in combination with observations on the sun, Polaris, and the brighter equatorial stars, for the determination and verification of time, latitude, and azimuth. In this practice, the data for the *sun* are required in terms of daily *apparent positions* for the Greenwich meridian; for all *stellar* positions in terms of the Greenwich meridian, *mean time*, and *mean time intervals*.

The apparent time of sunrise and of sunset, the refractions in polar distance, and the companion trigonometric tables and formulas employed in these methods, are tabulated in the Standard Field Tables of the Bureau of Land Management.

Other Technical Publications

The Superintendent of Documents, Government Printing Office, Washington, D.C. 20402, has for sale to the public at current cost of printing the following technical publications of the Bureau of Land Management.

The Manual of Instructions for the Survey of the Public Lands of the United States, 1947.

Standard Field Tables, 1956 (a supplement to the Manual of Surveying Instructions); contains traverse tables; stadia coefficients; 5-place natural and 6-place logarithmic sines, cosines, tangents, and cotangents; 6-place logarithms of numbers; and other tables and data of particular application in land surveying practice.

The Ephemeris, published annually.

Restoration of Lost or Obliterated Corners and Subdivisions of Sections, 1963 edition, reprint 1965; a compendium of the rules that are applicable within the area of the United States rectangular surveys, for the guidance of county and other local surveyors, with explanation of the methods relating to retracements.

		AT GREENWICH APPARENT NOON					POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME		
Date		THE SUN'S Apparent Declination	Diff. for 1 Hour	Semi-diam-eter	Time Semi-diam-eter Pass-ing Mer.	Equation of Time, Add to Apparent Time	Upper Cul-mination	Elongation Lat. 40°	Decli-nation
JANUARY, 1971									
									° ′ +89 08
		° ′ ″	″	′ ″	s	m s	h m	h m	″
Fri.	1	S23 02 07.1	+11.97	16 17.51	71	3 24.46	7 21.2 P.M.	W.E. 1 21.1 A.M.	17.70
Sat.	2	22 57 06.0	13.12	16 17.53	71	3 52.83	7 17.3	1 17.3	17.85
Sun.	3	22 51 37.5	14.26	16 17.54	71	4 20.83	7 13.3	1 13.4	17.98
Mon.	4	22 45 41.6	15.39	16 17.54	71	4 48.44	7 09.4	1 09.4	18.09
Tues.	5	22 39 18.6	16.52	16 17.54	71	5 15.63	7 05.4	1 05.5	18.20
Wed.	6	22 32 28.8	17.63	16 17.53	71	5 42.38	7 01.5	1 01.5	18.33
Thur.	7	22 25 12.3	18.74	16 17.52	71	6 08.64	6 57.5	0 57.6	18.46
Fri.	8	22 17 29.4	19.84	16 17.50	71	6 34.40	6 53.6	0 53.6	18.61
Sat.	9	22 09 20.2	20.92	16 17.48	71	6 59.65	6 49.6	0 49.7	18.77
Sun.	10	22 00 45.1	22.00	16 17.45	70	7 24.35	6 45.7	0 45.7	18.93
Mon.	11	21 51 44.2	23.07	16 17.41	70	7 48.49	6 41.7	0 41.8	19.09
Tues.	12	21 42 17.8	24.13	16 17.37	70	8 12.04	6 37.8	0 37.8	19.23
Wed.	13	21 32 26.2	25.17	16 17.32	70	8 35.00	6 33.8	0 33.9	19.36
Thur.	14	21 22 09.6	26.21	16 17.26	70	8 57.33	6 29.8	0 29.9	19.46
Fri.	15	21 11 28.3	27.23	16 17.20	70	9 19.02	6 25.9	0 26.0	19.54
Sat.	16	21 00 22.6	28.24	16 17.12	70	9 40.06	6 21.9	0 22.0	19.60
Sun.	17	20 48 52.7	29.24	16 17.05	70	10 00.44	6 18.0	0 18.1	19.65
Mon.	18	20 36 59.0	30.23	16 16.97	70	10 20.13	6 14.0	0 14.1	19.68
Tues.	19	20 24 41.9	31.20	16 16.89	70	10 39.12	6 10.1	0 10.1	19.71
Wed.	20	20 12 01.4	32.16	16 16.80	70	10 57.39	6 06.1	0 06.2	19.73
Thur.	21	19 58 58.1	33.11	16 16.71	69	11 14.94	6 02.2	0 02.2 A.M. 11 58.3 P.M.	19.77
Fri.	22	19 45 32.3	34.04	16 16.61	69	11 31.75	5 58.2	11 54.3	19.82
Sat.	23	19 31 44.4	34.95	16 16.51	69	11 47.81	5 54.3	11 50.4	19.88
Sun	24	19 17 34.8	35.85	16 16.40	69	12 03.10	5 50.3	11 46.4	19.96
Mon.	25	19 03 03.7	36.73	16 16.29	69	12 17.62	5 46.3	11 42.5	20.04
Tues.	26	18 48 11.7	37.60	16 16.18	69	12 31.35	5 42.4	11 38.5	20.12
Wed.	27	18 32 59.1	38.45	16 16.06	69	12 44.28	5 38.4	11 34.6	20.17
Thur.	28	18 17 26.3	39.28	16 15.94	69	12 56.40	5 34.5	11 30.6	20.19
Fri.	29	18 01 33.8	40.09	16 15.82	69	13 07.69	5 30.5	11 26.6	20.18
Sat.	30	17 45 22.0	40.89	16 15.69	68	13 18.15	5 26.6	11 22.7	20.13
Sun.	31	S17 28 51.2	+41.67	16 15.56	68	13 27.78	5 22.6 P.M.	W.E. 11 18.7 P.M.	20.07
FEBRUARY, 1971									
Mon.	1	S17 12 01.9	+42.43	16 15.43	68	13 36.57	5 18.6 P.M.	W.E. 11 14.8 P.M.	20.01
Tues.	2	16 54 54.5	43.18	16 15.30	68	13 44.53	5 14.7	11 10.8	19.95
Wed.	3	16 37 29.5	43.90	16 15.16	68	13 51.64	5 10.7	11 06.9	19.91
Thur.	4	16 19 47.1	44.62	16 15.01	68	13 57.92	5 06.8	11 02.9	19.87
Fri.	5	16 01 47.9	45.31	16 14.86	68	14 03.36	5 02.8	10 59.0	19.85
Sat.	6	15 43 32.3	45.98	16 14.71	68	14 07.99	4 58.9	10 55.0	19.83
Sun.	7	15 25 00.8	46.64	16 14.55	68	14 11.79	4 54.9	10 51.1	19.81
Mon.	8	15 06 13.6	47.29	16 14.38	67	14 14.79	4 51.0	10 47.1	19.78
Tues.	9	14 47 11.1	47.91	16 14.21	67	14 16.99	4 47.0	10 43.1	19.73
Wed.	10	14 27 53.8	48.52	16 14.04	67	14 18.40	4 43.1	10 39.2	19.66
Thur.	11	14 08 22.0	49.12	16 13.86	67	14 19.02	4 39.1	10 35.2	19.57
Fri.	12	13 48 36.2	49.70	16 13.67	67	14 18.89	4 35.1	10 31.3	19.46
Sat.	13	13 28 36.6	50.26	16 13.48	67	14 18.00	4 31.2	10 27.3	19.33
Sun.	14	13 08 23.8	50.80	16 13.29	67	14 16.37	4 27.2	10 23.4	19.19
Mon.	15	12 47 58.2	51.33	16 13.09	67	14 14.00	4 23.3	10 19.4	19.03
Tues.	16	S12 27 20.1	+51.84	16 12.89	67	14 10.92	4 19.3 P.M.	W.E. 10 15.5 P.M.	18.88

The sign + prefixed to the hourly change of declination indicates that { north / south } declinations are { increasing / decreasing }.

The sign − prefixed to the hourly change of declination indicates that { south / north } declinations are { increasing / decreasing }.

AT GREENWICH APPARENT NOON							POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME		
Date		THE SUN'S Apparent Declination	Diff. for 1 Hour	Semi-diameter	Time Semi-diameter Passing Mer.	Equation of Time, Add to Apparent Time	Upper Culmination	Elongation Lat. 40°	Declination
FEBRUARY, 1971									
		° ′ ″	″	′ ″	s	m s	h m	h m	° ′ +89 08 ″
Tues	16	S12 27 20.1	+51.84	16 12.89	67	14 10.92	4 19.3 P.M.	W.E. 10 15.5 P.M.	18.88
Wed.	17	12 06 29.8	52.34	16 12.68	67	14 07.15	4 15.4	10 11.5	18.74
Thur.	18	11 45 27.9	52.81	16 12.47	66	14 02.68	4 11.4	10 07.6	18.60
Fri.	19	11 24 14.7	53.28	16 12.26	66	13 57.54	4 07.5	10 03.6	18.48
Sat.	20	11 02 50.6	53.72	16 12.04	66	13 51.75	4 03.5	9 59.7	18.38
Sun.	21	10 41 16.1	54.15	16 11.82	66	13 45.30	3 59.6	9 55.7	18.28
Mon.	22	10 19 31.6	54.55	16 11.60	66	13 38.23	3 55.6	9 51.8	18.19
Tues.	23	9 57 37.5	54.94	16 11.37	66	13 30.53	3 51.7	9 47.8	18.08
Wed.	24	9 35 34.3	55.32	16 11.15	66	13 22.22	3 47.7	9 43.8	17.94
Thur.	25	9 13 22.3	55.67	16 10.92	66	13 13.32	3 43.8	9 39.9	17.78
Fri.	26	8 51 02.1	56.00	16 10.69	66	13 03.83	3 39.8	9 35.9	17.58
Sat.	27	8 28 34.1	56.32	16 10.46	66	12 53.77	3 35.9	9 32.0	17.36
Sun.	28	S 8 05 58.7	+56.62	16 10.23	66	12 43.14	3 31.9 P.M.	W.E. 9 28.0 P.M.	17.13
MARCH, 1971									
Mon.	1	S 7 43 16.2	+56.91	16 10.00	65	12 31.98	3 28.0 P.M.	W.E. 9 24.1 P.M.	16.90
Tues.	2	7 20 27.2	57.17	16 09.76	65	12 20.28	3 24.0	9 20.1	16.69
Wed.	3	6 57 32.1	57.42	16 09.53	65	12 08.06	3 20.1	9 16.2	16.49
Thur.	4	6 34 31.2	57.65	16 09.29	65	11 55.35	3 16.1	9 12.2	16.31
Fri.	5	6 11 25.0	57.86	16 09.05	65	11 42.17	3 12.2	9 08.3	16.13
Sat.	6	5 48 13.8	58.06	16 08.81	65	11 28.53	3 08.2	9 04.4	15.96
Sun.	7	5 24 58.0	58.25	16 08.56	65	11 14.45	3 04.3	9 00.4	15.78
Mon.	8	5 01 38.0	58.41	16 08.31	65	10 59.96	3 00.3	8 56.5	15.58
Tues.	9	4 38 14.1	58.57	16 08.06	65	10 45.08	2 56.4	8 52.5	15.37
Wed.	10	4 14 46.7	58.70	16 07.81	65	10 29.83	2 52.4	8 48.6	15.14
Thur.	11	3 51 16.3	58.83	16 07.55	65	10 14.24	2 48.5	8 44.6	14.89
Fri.	12	3 27 43.0	58.94	16 07.29	65	9 58.31	2 44.5	8 40.7	14.62
Sat.	13	3 04 07.2	59.04	16 07.03	65	9 42.09	2 40.6	8 36.7	14.34
Sun.	14	2 40 29.3	59.11	16 06.76	65	9 25.59	2 36.6	8 32.8	14.05
Mon.	15	2 16 49.8	59.18	16 06.49	65	9 08.83	2 32.7	8 28.8	13.76
Tues.	16	1 53 08.7	59.23	16 06.22	65	8 51.84	2 28.7	8 24.9	13.48
Wed.	17	1 29 26.6	59.27	16 05.95	65	8 34.65	2 24.8	8 20.9	13.21
Thur.	18	1 05 43.8	59.29	16 05.67	65	8 17.27	2 20.9	8 17.0	12.95
Fri.	19	0 42 00.7	59.30	16 05.40	65	7 59.72	2 16.9	8 13.0	12.71
Sat.	20	S 0 18 17.6	59.29	16 05.12	65	7 42.02	2 13.0	8 09.1	12.48
Sun.	21	N 0 05 25.2	59.27	16 04.84	64	7 24.21	2 09.0	8 05.2	12.26
Mon.	22	0 29 07.2	59.23	16 04.57	64	7 06.30	2 05.1	8 01.2	12.04
Tues.	23	0 52 48.0	59.17	16 04.29	64	6 48.30	2 01.1	7 57.3	11.80
Wed.	24	1 16 27.3	59.10	16 04.01	64	6 30.25	1 57.2	7 53.3	11.53
Thur.	25	1 40 04.6	59.01	16 03.73	64	6 12.14	1 53.3	7 49.4	11.24
Fri.	26	2 03 39.7	58.91	16 03.45	64	5 54.01	1 49.3	7 45.4	10.92
Sat.	27	2 27 12.1	58.79	16 03.18	64	5 35.86	1 45.4	7 41.5	10.59
Sun.	28	2 50 41.4	58.65	16 02.90	64	5 17.70	1 41.4	7 37.6	10.25
Mon.	29	3 14 07.3	58.50	16 02.63	64	4 59.57	1 37.5	7 33.6	09.93
Tues.	30	3 37 29.3	58.33	16 02.35	64	4 41.47	1 33.6	7 29.7	09.63
Wed.	31	4 00 47.2	58.15	16 02.08	64	4 23.42	1 29.6	7 25.8	09.35
Thur.	32	N 4 24 00.4	+57.95	16 01.81	64	4 05.42	1 25.7 P.M.	W.E. 7 21.8 P.M.	09.09

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The sign − prefixed to the hourly change of declination indicates that { south / north } declinations are { increasing. / decreasing. }

AT GREENWICH APPARENT NOON							POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME		
	THE SUN'S								
Date		Apparent Declination	Diff. for 1 Hour	Semi – diam – eter	Time Semi–diam–eter Pass–ing Mer.	Equation of Time, Add to / Subtract from Apparent Time	Upper Cul – mination	Elongation Lat. 40°	Decli – nation
APRIL, 1971									
		° ′ ″	″	′ ″	s	m s	h m	h m	° ′ +89 07 ″
Thur.	1	N 4 24 00.4	+57.95	16 01.81	64	4 05.42	1 25.7 P.M.	W.E. 7 21.8 P.M.	69.09
Fri.	2	4 47 08.8	57.74	16 01.54	65	3 47.51	1 21.8	7 17.9	68.83
Sat.	3	5 10 11.9	57.51	16 01.27	65	3 29.71	1 17.8	7 13.9	68.57
Sun.	4	5 33 09.4	57.27	16 01.00	65	3 12.03	1 13.9	7 10.0	68.30
Mon.	5	5 56 01.0	57.02	16 00.73	65	2 54.50	1 09.9	7 06.1	68.01
Tues.	6	6 18 46.2	56.75	16 00.46	65	2 37.12	1 06.0	7 02.1	67.71
Wed.	7	6 41 24.9	56.47	16 00.19	65	2 19.92	1 02.1	6 58.2	67.40
Thur.	8	7 03 56.7	56.17	15 59.91	65	2 02.93	12 58.1	6 54.2	67.07
Fri.	9	7 26 21.2	55.86	15 59.65	65	1 46.17	12 54.2	6 50.3	66.72
Sat.	10	7 48 38.2	55.55	15 59.38	65	1 29.64	12 50.3	6 46.4	66.38
Sun.	11	8 10 47.4	55.21	15 59.10	65	1 13.38	12 46.3	6 42.4	66.03
Mon.	12	8 32 48.4	54.86	15 58.83	65	0 57.41	12 42.4	6 38.5	65.69
Tues.	13	8 54 40.9	54.50	15 58.56	65	0 41.73	12 38.5	6 34.6	65.36
Wed.	14	9 16 24.6	54.13	15 58.28	65	0 26.38	12 34.5	6 30.7	65.05
Thur.	15	9 37 59.2	53.75	15 58.01	65	0 11.37	12 30.6	6 26.7	64.76
Fri.	16	9 59 24.4	53.34	15 57.74	65	0 03.28	12 26.7	6 22.8	64.48
Sat.	17	10 20 39.7	52.93	15 57.46	65	0 17.55	12 22.7	6 18.9	64.22
Sun.	18	10 41 45.0	52.50	15 57.19	65	0 31.43	12 18.8	6 14.9	63.96
Mon.	19	11 02 39.8	52.06	15 56.92	65	0 44.91	12 14.9	6 11.0	63.69
Tues.	20	11 23 23.8	51.60	15 56.65	65	0 57.95	12 10.9	6 07.1	63.40
Wed.	21	11 43 56.7	51.13	15 56.39	65	1 10.55	12 07.0	6 03.1	63.09
Thur.	22	12 04 18.0	50.64	15 56.12	65	1 22.71	12 03.1 P.M.	W.E. 5 59.2 P.M.	62.76
Fri.	23	12 24 27.5	50.14	15 55.86	65	1 34.41	11 59.1 A.M.	E.E. 6 03.0 A.M.	62.41
Sat.	24	12 44 24.8	49.62	15 55.60	65	1 45.65	11 55.2	5 59.1	62.06
Sun.	25	13 04 09.4	49.09	15 55.35	66	1 56.41	11 51.3	5 55.2	61.72
Mon.	26	13 23 41.2	48.55	15 55.10	66	2 06.70	11 47.4	5 51.2	61.40
Tues.	27	13 42 59.7	47.99	15 54.85	66	2 16.50	11 43.4	5 47.3	61.10
Wed.	28	14 02 04.6	47.41	15 54.60	66	2 25.80	11 39.5	5 43.4	60.83
Thur.	29	14 20 55.6	46.83	15 54.36	66	2 34.62	11 35.6	5 39.5	60.57
Fri.	30	N14 39 32.3	+46.23	15 54.12	66	2 42.93	11 31.7 A.M.	E.E. 5 35.5 A.M.	60.32
MAY, 1971									
Sat.	1	N14 57 54.4	+45.61	15 53.89	66	2 50.73	11 27.7 A.M.	E.E. 5 31.6 A.M.	60.06
Sun.	2	15 16 01.6	44.98	15 53.66	66	2 58.01	11 23.8	5 27.7	59.79
Mon.	3	15 33 53.5	44.34	15 53.43	66	3 04.78	11 19.9	5 23.8	59.51
Tues.	4	15 51 29.9	43.69	15 53.20	66	3 11.01	11 16.0	5 19.8	59.21
Wed.	5	16 08 50.5	43.02	15 52.97	66	3 16.70	11 12.0	5 15.9	58.91
Thur.	6	16 25 54.9	42.34	15 52.74	66	3 21.85	11 08.1	5 12.0	58.59
Fri.	7	16 42 43.0	41.66	15 52.52	66	3 26.45	11 04.2	5 08.1	58.27
Sat.	8	16 59 14.4	40.95	15 52.30	67	3 30.50	11 00.3	5 04.1	57.95
Sun.	9	17 15 28.7	40.24	15 52.08	67	3 33.98	10 56.3	5 00.2	57.63
Mon.	10	17 31 25.9	39.52	15 51.86	67	3 36.90	10 52.4	4 56.3	57.34
Tues.	11	17 47 05.5	38.78	15 51.64	67	3 39.24	10 48.5	4 52.4	57.06
Wed.	12	18 02 27.3	38.03	15 51.43	67	3 41.01	10 44.6	4 48.5	56.80
Thur.	13	18 17 31.0	37.27	15 51.21	67	3 42.20	10 40.7	4 44.5	56.56
Fri.	14	18 32 16.4	36.50	15 51.00	67	3 42.81	10 36.8	4 40.6	56.34
Sat.	15	18 46 43.1	35.72	15 50.79	67	3 42.83	10 32.8	4 36.7	56.12
Sun.	16	N19 00 50.9	+34.92	15 50.59	67	3 42.26	10 28.9 A.M.	E.E. 4 32.8 A.M.	55.90

The sign + prefixed to the hourly change of declination indicates that {north / south} declinations are {increasing / decreasing}.

The sign − prefixed to the hourly change of declination indicates that {south / north} declinations are {increasing / decreasing}.

For time of Western Elongation of Polaris for any date after April 22nd, add $5^h\ 56.1^m$ to the time of Upper Culmination of the same date.

AT GREENWICH APPARENT NOON							POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME			
Date		THE SUN'S Apparent Declination	THE SUN'S Diff. for 1 Hour	THE SUN'S Semi-diameter	Time Semi-diameter Passing Mer.	Equation of Time, Subtract from / Add to Apparent Time	Upper Culmination	Elongation Lat. 40°		Declination
MAY, 1971										
										° ′ +89 07
		° ′ ″	″	′ ″	s	m s	h m		h m	″
Sun.	16	N19 00 50.9	+34.92	15 50.59	67	3 42.26	10 28.9 A.M.	E.E.	4 32.8 A.M.	55.90
Mon.	17	19 14 39.4	34.12	15 50.38	67	3 41.12	10 25.0		4 28.9	55.67
Tues.	18	19 28 08.5	33.30	15 50.18	67	3 39.39	10 21.1		4 24.9	55.43
Wed.	19	19 41 17.8	32.47	15 49.98	67	3 37.08	10 17.1		4 21.0	55.16
Thur.	20	19 54 07.0	31.63	15 49.79	68	3 34.19	10 13.2		4 17.1	54.88
Fri.	21	20 06 35.9	30.77	15 49.60	68	3 30.75	10 09.3		4 13.2	54.59
Sat.	22	20 18 44.1	29.91	15 49.41	68	3 26.75	10 05.4		4 09.3	54.31
Sun.	23	20 30 31.6	29.04	15 49.23	68	3 22.22	10 01.5		4 05.4	54.05
Mon.	24	20 41 57.8	28.15	15 49.06	68	3 17.15	9 57.6		4 01.4	53.81
Tues.	25	20 53 02.7	27.26	15 48.89	68	3 11.57	9 53.7		3 57.5	53.60
Wed.	26	21 03 46.1	26.35	15 48.72	68	3 05.50	9 49.7		3 53.6	53.42
Thur.	27	21 14 07.6	25.44	15 48.56	68	2 58.95	9 45.8		3 49.7	53.24
Fri.	28	21 24 07.1	24.51	15 48.40	68	2 51.94	9 41.9		3 45.8	53.07
Sat.	29	21 33 44.3	23.58	15 48.25	68	2 44.48	9 38.0		3 41.9	52.89
Sun.	30	21 42 59.0	22.64	15 48.10	68	2 36.58	9 34.1		3 38.0	52.70
Mon.	31	N21 51 51.0	+21.69	15 47.96	68	2 28.27	9 30.2 A.M.	E.E.	3 34.0 A.M.	52.50
JUNE, 1971										
Tues.	1	N22 00 20.2	+20.74	15 47.82	68	2 19.56	9 26.2 A.M.	E.E.	3 30.1 A.M.	52.29
Wed.	2	22 08 26.4	19.78	15 47.69	68	2 10.46	9 22.3		3 26.2	52.06
Thur.	3	22 16 09.4	18.80	15 47.56	68	2 00.99	9 18.4		3 22.3	51.84
Fri.	4	22 23 29.0	17.83	15 47.43	69	1 51.17	9 14.5		3 18.4	51.61
Sat.	5	22 30 25.1	16.85	15 47.30	69	1 41.01	9 10.6		3 14.5	51.39
Sun.	6	22 36 57.7	15.86	15 47.18	69	1 30.52	9 06.7		3 10.6	51.19
Mon.	7	22 43 06.5	14.87	15 47.06	69	1 19.73	9 02.8		3 06.6	51.00
Tues.	8	22 48 51.4	13.87	15 46.94	69	1 08.65	8 58.9		3 02.7	50.84
Wed.	9	22 54 12.3	12.87	15 46.83	69	0 57.29	8 55.0		2 58.8	50.70
Thur.	10	22 59 09.2	11.86	15 46.72	69	0 45.68	8 51.0		2 54.9	50.59
Fri.	11	23 03 41.8	10.85	15 46.61	69	0 33.83	8 47.1		2 51.0	50.48
Sat.	12	23 07 50.2	9.84	15 46.50	69	0 21.75	8 43.2		2 47.1	50.38
Sun.	13	23 11 34.2	8.82	15 46.40	69	0 09.48	8 39.3		2 43.2	50.26
Mon.	14	23 14 53.5	7.79	15 46.30	69	0 02.99	8 35.4		2 39.3	50.14
Tues.	15	23 17 48.3	6.77	15 46.21	69	0 15.63	8 31.5		2 35.4	49.99
Wed.	16	23 20 18.5	5.74	15 46.12	69	0 28.41	8 27.6		2 31.4	49.83
Thur.	17	23 22 23.9	4.71	15 46.03	69	0 41.32	8 23.7		2 27.5	49.66
Fri.	18	23 24 04.5	3.68	15 45.95	69	0 54.32	8 19.7		2 23.6	49.50
Sat.	19	23 25 20.3	2.64	15 45.87	69	1 07.39	8 15.8		2 19.7	49.35
Sun.	20	23 26 11.2	1.60	15 45.80	69	1 20.52	8 11.9		2 15.8	49.23
Mon.	21	23 26 37.3	+ 0.57	15 45.74	69	1 33.66	8 08.0		2 11.9	49.13
Tues.	22	23 26 38.5	− 0.46	15 45.68	69	1 46.79	8 04.1		2 08.0	49.06
Wed.	23	23 26 15.0	1.50	15 45.63	69	1 59.88	8 00.2		2 04.1	49.01
Thur.	24	23 25 26.6	2.53	15 45.58	69	2 12.90	7 56.3		2 00.2	48.96
Fri.	25	23 24 13.4	3.56	15 45.53	69	2 25.83	7 52.4		1 56.3	48.92
Sat.	26	23 22 35.5	4.59	15 45.49	69	2 38.63	7 48.5		1 52.4	48.86
Sun.	27	23 20 33.0	5.62	15 45.46	69	2 51.28	7 44.6		1 48.4	48.80
Mon.	28	23 18 05.8	6.65	15 45.44	69	3 03.76	7 40.7		1 44.5	48.72
Tues.	29	23 15 14.0	7.67	15 45.41	69	3 16.05	7 36.8		1 40.6	48.64
Wed.	30	23 11 57.8	8.68	15 45.40	69	3 28.10	7 32.8		1 36.7	48.55
Thur.	31	N23 08 17.2	− 9.69	15 45.39	69	3 39.91	7 28.9 A.M.	E.E.	1 32.8 A.M.	48.46

The sign + prefixed to the hourly change of declination indicates that { north / south } declinations are { increasing. / decreasing. }

The sign − prefixed to the hourly change of declination indicates that { south / north } declinations are { increasing. / decreasing. }

AT GREENWICH APPARENT NOON						POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME		
Date	THE SUN'S Apparent Declination	Diff for 1 Hour	Semi-diameter	Time Semi-diameter Passing Mer.	Equation of Time, Add to Apparent Time	Upper Culmination	Elongation Lat. 40°	Declination
JULY, 1971								
	° ′ ″	″	′ ″	s	m s	h m	h m	° ′ +89 07 ″
Thur. 1	N23 08 17.2	− 9.69	15 45.39	69	3 39.91	7 28.9 A.M.	E.E. 1 32.8 A.M.	48.46
Fri. 2	23 04 12.5	10.70	15 45.38	69	3 51.46	7 25.0	1 28.9	48.37
Sat. 3	22 59 43.5	11.71	15 45.37	69	4 02.72	7 21.1	1 25.0	48.30
Sun. 4	22 54 50.5	12.70	15 45.37	69	4 13.67	7 17.2	1 21.1	48.24
Mon. 5	22 49 33.7	13.70	15 45.37	69	4 24.30	7 13.3	1 17.2	48.21
Tues. 6	22 43 53.1	14.69	15 45.38	69	4 34.58	7 09.4	1 13.3	48.20
Wed. 7	22 37 48.8	15.66	15 45.39	68	4 44.50	7 05.5	1 09.4	48.22
Thur. 8	22 31 21.2	16.64	15 45.40	68	4 54.06	7 01.6	1 05.5	48.25
Fri. 9	22 24 30.2	17.61	15 45.42	68	5 03.22	6 57.7	1 01.6	48.29
Sat. 10	22 17 16.0	18.57	15 45.43	68	5 11.99	6 53.8	0 57.7	48.33
Sun. 11	22 09 38.7	19.53	15 45.46	68	5 20.34	6 49.9	0 53.7	48.35
Mon. 12	22 01 38.6	20.48	15 45.48	68	5 28.27	6 46.0	0 49.8	48.35
Tues. 13	21 53 15.8	21.42	15 45.51	68	5 35.76	6 42.0	0 45.9	48.34
Wed. 14	21 44 30.4	22.36	15 45.55	68	5 42.80	6 38.1	0 42.0	48.32
Thur. 15	21 35 22.6	23.29	15 45.58	68	5 49.39	6 34.2	0 38.1	48.29
Fri. 16	21 25 52.7	24.20	15 45.62	68	5 55.49	6 30.3	0 34.2	48.28
Sat. 17	21 16 00.8	25.12	15 45.67	68	6 01.10	6 26.4	0 30.3	48.29
Sun. 18	21 05 47.1	26.02	15 45.72	68	6 06.21	6 22.5	0 26.4	48.33
Mon. 19	20 55 12.0	26.90	15 45.78	68	6 10.80	6 18.6	0 22.5	48.39
Tues. 20	20 44 15.7	27.79	15 45.84	68	6 14.86	6 14.7	0 18.6	48.48
Wed. 21	20 32 58.3	28.65	15 45.91	68	6 18.37	6 10.8	0 14.7	48.58
Thur. 22	20 21 20.3	29.51	15 45.98	67	6 21.33	6 06.9	0 10.8	48.68
Fri. 23	20 09 21.8	30.36	15 46.06	67	6 23.72	6 03.0	0 06.9	48.77
Sat. 24	19 57 03.1	31.19	15 46.15	67	6 25.52	5 59.1	{ 0 03.0 A.M. 11 59.1 P.M. }	48.86
Sun. 25	19 44 24.5	32.02	15 46.24	67	6 26.72	5 55.2	11 55.1	48.93
Mon. 26	19 31 26.2	32.83	15 46.33	67	6 27.32	5 51.3	11 51.2	49.00
Tues. 27	19 18 08.5	33.63	15 46.43	67	6 27.32	5 47.4	11 47.3	49.05
Wed. 28	19 04 31.8	34.42	15 46.54	67	6 26.70	5 43.5	11 43.4	49.11
Thur. 29	18 50 36.2	35.20	15 46.65	67	6 25.46	5 39.5	11 39.5	49.16
Fri. 30	18 36 22.1	35.97	15 46.76	67	6 23.61	5 35.6	11 35.6	49.23
Sat. 31	N18 21 49.8	−36.72	15 46.87	67	6 21.13	5 31.7 A.M.	E.E. 11 31.7 P.M.	49.31
AUGUST, 1971								
Sun. 1	N18 06 59.5	−37.46	15 47.00	67	6 18.02	5 27.8 A.M.	E.E. 11 27.8 P.M.	49.41
Mon. 2	17 51 51.6	38.19	15 47.12	67	6 14.30	5 23.9	11 23.9	49.54
Tues. 3	17 36 26.3	38.91	15 47.25	66	6 09.96	5 20.0	11 20.0	49.69
Wed. 4	17 20 44.0	39.61	15 47.38	66	6 04.99	5 16.1	11 16.1	49.86
Thur. 5	17 04 44.9	40.31	15 47.52	66	5 59.41	5 12.2	11 12.2	50.04
Fri. 6	16 48 29.3	40.99	15 47.65	66	5 53.23	5 08.3	11 08.3	50.22
Sat. 7	16 31 57.5	41.66	15 47.79	66	5 46.45	5 04.4	11 04.4	50.40
Sun. 8	16 15 09.6	42.32	15 47.93	66	5 39.08	5 00.5	11 00.4	50.55
Mon. 9	15 58 06.1	42.97	15 48.08	66	5 31.13	4 56.6	10 56.5	50.69
Tues. 10	15 40 47.1	43.61	15 48.23	66	5 22.61	4 52.7	10 52.6	50.81
Wed. 11	15 23 12.9	44.23	15 48.38	66	5 13.53	4 48.8	10 48.7	50.92
Thur. 12	15 05 23.9	44.85	15 48.53	66	5 03.91	4 44.8	10 44.8	51.05
Fri. 13	14 47 20.3	45.45	15 48.69	66	4 53.74	4 40.9	10 40.9	51.19
Sat. 14	14 29 02.4	46.04	15 48.85	66	4 43.04	4 37.0	10 37.0	51.35
Sun. 15	14 10 30.5	46.61	15 49.01	65	4 31.81	4 33.1	10 33.1	51.55
Mon. 16	N13 51 45.1	−47.17	15 49.18	65	4 20.06	4 29.2 A.M.	E.E. 10 29.2 P.M.	51.76

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The sign − prefixed to the hourly change of declination indicates that { south / north } declinations are { increasing / decreasing }.

Date		AT GREENWICH APPARENT NOON: THE SUN'S Apparent Declination	Diff. for 1 Hour	Semi-diameter	Time Semi-diameter Passing Mer.	Equation of Time, Add to / Subtract from Apparent Time	POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME: Upper Culmination		Elongation Lat. 40°		Declination
AUGUST, 1971											° ′ +89 07
		° ′ ″	″	′ ″	s	m s	h m			h m	″
Mon.	16	N13 51 45.1	−47.17	15 49.18	65	4 20.06	4 29.2 A.M.	E.E.	10 29.2 P.M.		51.76
Tues.	17	13 32 46.4	47.72	15 49.35	65	4 07.81	4 25.3		10 25.3		51.99
Wed.	18	13 13 34.7	48.25	15 49.53	65	3 55.06	4 21.4		10 21.4		52.23
Thur.	19	12 54 10.4	48.77	15 49.71	65	3 41.80	4 17.5		10 17.5		52.46
Fri.	20	12 34 33.8	49.27	15 49.90	65	3 28.05	4 13.6		10 13.6		52.68
Sat.	21	12 14 45.4	49.76	15 50.09	65	3 13.83	4 09.7		10 09.6		52.90
Sun.	22	11 54 45.2	50.24	15 50.28	65	2 59.14	4 05.8		10 05.7		53.10
Mon.	23	11 34 33.8	50.70	15 50.48	65	2 43.99	4 01.9		10 01.8		53.29
Tues.	24	11 14 11.5	51.15	15 50.68	65	2 28.39	3 57.9		9 57.9		53.47
Wed.	25	10 53 38.6	51.59	15 50.89	65	2 12.35	3 54.0		9 54.0		53.65
Thur.	26	10 32 55.4	52.01	15 51.10	65	1 55.88	3 50.1		9 50.1		53.85
Fri.	27	10 12 02.2	52.41	15 51.32	65	1 39.01	3 46.2		9 46.2		54.05
Sat.	28	9 50 59.5	52.80	15 51.53	65	1 21.73	3 42.3		9 42.3		54.27
Sun.	29	9 29 47.6	53.18	15 51.76	65	1 04.07	3 38.4		9 38.4		54.51
Mon.	30	9 08 26.7	53.55	15 51.98	64	0 46.04	3 34.5		9 34.5		54.77
Tues.	31	N 8 46 57.1	−53.91	15 52.21	64	0 27.65	3 30.6 A.M.	E.E.	9 30.6 P.M.		55.06
SEPTEMBER, 1971											
Wed.	1	N 8 25 19.2	−54.24	15 52.44	64	0 08.93	3 26.7 A.M.	E.E.	9 26.6 P.M.		55.35
Thur.	2	8 03 33.4	54.57	15 52.67	64	0 10.11	3 22.8		9 22.7		55.66
Fri.	3	7 41 39.9	54.88	15 52.90	64	0 29.44	3 18.9		9 18.8		55.96
Sat.	4	7 19 39.0	55.19	15 53.13	64	0 49.06	3 14.9		9 14.9		56.25
Sun.	5	6 57 31.0	55.48	15 53.37	64	1 08.93	3 11.0		9 11.0		56.51
Mon.	6	6 35 16.2	55.75	15 53.60	64	1 29.03	3 07.1		9 07.1		56.76
Tues.	7	6 12 54.8	56.02	15 53.84	64	1 49.35	3 03.2		9 03.2		56.99
Wed.	8	5 50 27.1	56.28	15 54.08	64	2 09.84	2 59.3		8 59.3		57.23
Thur.	9	5 27 53.5	56.52	15 54.31	64	2 30.52	2 55.4		8 55.3		57.47
Fri.	10	5 05 14.3	56.75	15 54.55	64	2 51.33	2 51.5		8 51.4		57.74
Sat.	11	4 42 29.7	56.96	15 54.80	64	3 12.26	2 47.6		8 47.5		58.04
Sun.	12	4 19 40.0	57.17	15 55.04	64	3 33.30	2 43.6		8 43.6		58.36
Mon.	13	3 56 45.7	57.35	15 55.28	64	3 54.42	2 39.7		8 39.7		58.70
Tues.	14	3 33 47.1	57.52	15 55.53	64	4 15.62	2 35.8		8 35.8		59.04
Wed.	15	3 10 44.6	57.68	15 55.78	64	4 36.87	2 31.9		8 31.9		59.38
Thur.	16	2 47 38.4	57.83	15 56.04	64	4 58.15	2 28.0		8 27.9		59.71
Fri.	17	2 24 29.0	57.95	15 56.29	64	5 19.44	2 24.1		8 24.0		60.03
Sat.	18	2 01 16.6	58.07	15 56.55	64	5 40.73	2 20.2		8 20.1		60.34
Sun.	19	1 38 01.8	58.16	15 56.81	64	6 02.00	2 16.2		8 16.2		60.63
Mon.	20	1 14 44.8	58.25	15 57.08	64	6 23.24	2 12.3		8 12.3		60.92
Tues.	21	0 51 25.9	58.32	15 57.34	64	6 44.43	2 08.4		8 08.4		61.20
Wed.	22	0 28 05.5	58.37	15 57.61	64	7 05.54	2 04.5		8 04.5		61.48
Thur.	23	N 0 04 44.0	58.41	15 57.88	64	7 26.56	2 00.6		8 00.5		61.78
Fri.	24	S 0 18 38.3	58.44	15 58.16	64	7 47.48	1 56.7		7 56.6		62.08
Sat.	25	0 42 01.0	58.45	15 58.43	64	8 08.27	1 52.7		7 52.7		62.41
Sun.	26	1 05 23.8	58.44	15 58.71	64	8 28.92	1 48.8		7 48.8		62.75
Mon.	27	1 28 46.3	58.43	15 58.99	64	8 49.41	1 44.9		7 44.9		63.12
Tues.	28	1 52 08.2	58.39	15 59.27	64	9 09.71	1 41.0		7 41.0		63.49
Wed.	29	2 15 29.0	58.34	15 59.55	64	9 29.81	1 37.1		7 37.0		63.88
Thur.	30	2 38 48.4	58.28	15 59.83	64	9 49.69	1 33.2		7 33.1		64.27
Fri.	31	S 3 02 06.3	−58.20	16 00.11	64	10 09.33	1 29.2 A.M.	E.E.	7 29.2 P.M.		64.64

The sign + prefixed to the hourly change of declination indicates that {north / south} declinations are {increasing. / decreasing.}

The sign − prefixed to the hourly change of declination indicates that {south / north} declinations are {increasing. / decreasing.}

Date		AT GREENWICH APPARENT NOON					POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME		
		THE SUN'S			Time Semi-diameter Passing Mer.	Equation of Time Subtract from Apparent Time	Upper Culmination	Elongation Lat. 40	Declination
		Apparent Declination	Diff. for 1 Hour	Semi-diameter					
		OCTOBER, 1971							
		° ′ ″	″	′ ″	s	m s	h m	h m	° ′ +89 08 ″
Fri.	1	S 3 02 06.3	−58.20	16 00.11	64	10 09.33	1 29.2 A.M.	E.E. 7 29.2 P.M.	04.64
Sat.	2	3 25 22.1	58.11	16 00.39	64	10 28.70	1 25.3	7 25.3	05.00
Sun.	3	3 48 35.6	58.01	16 00.67	64	10 47.78	1 21.4	7 21.4	05.34
Mon.	4	4 11 46.4	57.89	16 00.95	64	11 06.54	1 17.5	7 17.4	05.65
Tues.	5	4 34 54.3	57.76	16 01.22	64	11 24.96	1 13.6	7 13.5	05.96
Wed.	6	4 57 59.0	57.62	16 01.50	65	11 43.02	1 09.6	7 09.6	06.27
Thur.	7	5 21 00.1	57.46	16 01.77	65	12 00.69	1 05.7	7 05.7	06.61
Fri.	8	5 43 57.2	57.29	16 02.04	65	12 17.94	1 01.8	7 01.8	06.96
Sat.	9	6 06 50.1	57.11	16 02.31	65	12 34.76	0 57.9	6 57.8	07.35
Sun.	10	6 29 38.3	56.90	16 02.58	65	12 51.13	0 54.0	6 53.9	07.75
Mon.	11	6 52 21.5	56.69	16 02.85	65	13 07.01	0 50.0	6 50.0	08.16
Tues.	12	7 14 59.3	56.45	16 03.13	65	13 22.40	0 46.1	6 46.1	08.56
Wed.	13	7 37 31.2	56.20	16 03.40	65	13 37.27	0 42.2	6 42.1	08.96
Thur.	14	7 59 57.0	55.94	16 03.67	65	13 51.62	0 38.3	6 38.2	09.34
Fri.	15	8 22 16.1	55.65	16 03.94	65	14 05.42	0 34.3	6 34.3	09.71
Sat.	16	8 44 28.3	55.35	16 04.21	65	14 18.65	0 30.4	6 30.4	10.07
Sun.	17	9 06 33.0	55.04	16 04.48	65	14 31.31	0 26.5	6 26.4	10.41
Mon.	18	9 28 30.0	54.70	16 04.75	65	14 43.36	0 22.6	6 22.5	10.74
Tues.	19	9 50 18.7	54.35	16 05.03	65	14 54.81	0 18.6	6 18.6	11.08
Wed.	20	10 11 58.9	53.99	16 05.30	66	15 05.65	0 14.7	6 14.7	11.42
Thur.	21	10 33 30.0	53.60	16 05.57	66	15 15.85	0 10.8	6 10.8	11.77
Fri.	22	10 54 51.7	53.20	16 05.85	66	15 25.40	0 06.9	6 06.8	12.13
Sat.	23	11 16 03.6	52.78	16 06.12	66	15 34.28	{ 0 03.0 A.M. / 11 59.0 P.M. }	E.E. 6 02.9 P.M.	{ 12.51 / 12.91
Sun.	24	11 37 05.3	52.35	16 06.39	66	15 42.50	11 55.1	W.E. 5 55.2 A.M.	13.31
Mon.	25	11 57 56.4	51.90	16 06.66	66	15 50.04	11 51.2	5 51.2	13.73
Tues.	26	12 18 36.3	51.43	16 06.93	66	15 56.87	11 47.2	5 47.3	14.15
Wed.	27	12 39 04.9	50.94	16 07.20	66	16 02.99	11 43.3	5 43.4	14.56
Thur.	28	12 59 21.5	50.44	16 07.47	66	16 08.40	11 39.4	5 39.4	14.96
Fri.	29	13 19 25.9	49.92	16 07.74	66	16 13.07	11 35.5	5 35.5	15.33
Sat.	30	13 39 17.7	49.39	16 08.00	67	16 17.00	11 31.5	5 31.6	15.68
Sun.	31	S13 58 56.5	−48.84	16 08.26	67	16 20.18	11 27.6 P.M.	W.E. 5 27.6 A.M.	16.01
		NOVEMBER, 1971							
Mon.	1	S14 18 21.9	−48.27	16 08.52	67	16 22.58	11 23.7 P.M.	W.E. 5 23.7 A.M.	16.34
Tues.	2	14 37 33.5	47.69	16 08.77	67	16 24.19	11 19.7	5 19.8	16.68
Wed.	3	14 56 31.0	47.09	16 09.02	67	16 25.00	11 15.8	5 15.9	17.04
Thur.	4	15 15 14.0	46.48	16 09.27	67	16 25.00	11 11.9	5 11.9	17.43
Fri.	5	15 33 42.1	45.85	16 09.51	67	16 24.17	11 08.0	5 08.0	17.84
Sat.	6	15 51 54.9	45.21	16 09.75	67	16 22.50	11 04.0	5 04.1	18.26
Sun.	7	16 09 52.1	44.55	16 09.99	68	16 19.99	11 00.1	5 00.1	18.68
Mon.	8	16 27 33.1	43.86	16 10.22	68	16 16.62	10 56.2	4 56.2	19.09
Tues.	9	16 44 57.6	43.17	16 10.45	68	16 12.39	10 52.2	4 52.3	19.48
Wed.	10	17 02 05.2	42.46	16 10.67	68	16 07.29	10 48.3	4 48.3	19.86
Thur.	11	17 18 55.5	41.73	16 10.90	68	16 01.33	10 44.3	4 44.4	20.21
Fri.	12	17 35 28.0	40.97	16 11.12	68	15 54.49	10 40.4	4 40.5	20.55
Sat.	13	17 51 42.2	40.20	16 11.34	68	15 46.80	10 36.5	4 36.5	20.88
Sun.	14	18 07 37.8	39.42	16 11.56	68	15 38.24	10 32.5	4 32.6	21.21
Mon.	15	18 23 14.5	38.63	16 11.77	68	15 28.82	10 28.6	4 28.7	21.53
Tues.	16	S18 38 31.8	−37.81	16 11.99	69	15 18.54	10 24.7 P.M.	W.E. 4 24.7 A.M.	21.86

The sign + prefixed to the hourly change of declination indicates that {north / south} declinations are {increasing / decreasing}.

The sign − prefixed to the hourly change of declination indicates that {south / north} declinations are {increasing / decreasing}.

For time of Eastern Elongation of Polaris for any date after October 23rd, subtract $5^h\ 56.1^m$ from the time of Upper Culmination of the same date.

AT GREENWICH APPARENT NOON								POLARIS FOR THE MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME		
Date		THE SUN'S Apparent Declination	THE SUN'S Diff. for 1 Hour	THE SUN'S Semi-diameter	Time Semi-diameter Passing Mer.	Equation of Time, Subtract from / Add to Apparent Time	Upper Culmination		Elongation Lat. 40°	Declination
NOVEMBER, 1971										
		° ′ ″	″	′ ″	s	m s	h m		h m	° ′ +89 08 ″
Tues.	16	S18 38 31.8	−37.81	16 11.99	69	15 18.54	10 24.7 P.M.	W.E.	4 24.7 A.M.	21.86
Wed.	17	18 53 29.3	36.98	16 12.20	69	15 07.41	10 20.7		4 20.8	22.20
Thur.	18	19 08 06.6	36.13	16 12.41	69	14 55.44	10 16.8		4 16.9	22.56
Fri.	19	19 22 23.4	35.26	16 12.61	69	14 42.63	10 12.9		4 12.9	22.93
Sat.	20	19 36 19.1	34.38	16 12.82	69	14 29.01	10 08.9		4 09.0	23.31
Sun.	21	19 49 53.5	33.48	16 13.02	69	14 14.58	10 05.0		4 05.1	23.70
Mon.	22	20 03 06.2	32.57	16 13.22	69	13 59.36	10 01.1		4 01.1	24.09
Tues.	23	20 15 56.9	31.64	16 13.42	69	13 43.34	9 57.1		3 57.2	24.47
Wed.	24	20 28 25.0	30.70	16 13.61	69	13 26.56	9 53.2		3 53.2	24.83
Thur.	25	20 40 30.4	29.74	16 13.80	70	13 09.03	9 49.2		3 49.3	25.18
Fri.	26	20 52 12.6	28.77	16 13.99	70	12 50.76	9 45.3		3 45.3	25.50
Sat.	27	21 03 31.5	27.79	16 14.18	70	12 31.76	9 41.3		3 41.4	25.79
Sun.	28	21 14 26.5	26.79	16 14.35	70	12 12.07	9 37.4		3 37.5	26.08
Mon.	29	21 24 57.4	25.78	16 14.53	70	11 51.67	9 33.5		3 33.5	26.37
Tues.	30	S21 35 04.0	−24.76	16 14.70	70	11 30.59	9 29.5 P.M.	W.E.	3 29.6 A.M.	26.67
DECEMBER, 1971										
Wed.	1	S21 44 46.0	−23.73	16 14.86	70	11 08.85	9 25.6 P.M.	W.E.	3 25.6 A.M.	26.99
Thur.	2	21 54 03.2	22.69	16 15.02	70	10 46.46	9 21.6		3 21.7	27.33
Fri.	3	22 02 55.1	21.63	16 15.17	70	10 23.44	9 17.7		3 17.8	27.69
Sat.	4	22 11 21.6	20.57	16 15.32	70	9 59.79	9 13.8		3 13.8	28.05
Sun.	5	22 19 22.5	19.49	16 15.46	70	9 35.55	9 09.8		3 09.9	28.40
Mon.	6	22 26 57.3	18.41	16 15.59	71	9 10.74	9 05.9		3 05.9	28.74
Tues.	7	22 34 06.0	17.31	16 15.72	71	8 45.37	9 01.9		3 02.0	29.06
Wed.	8	22 40 48.2	16.20	16 15.85	71	8 19.48	8 58.0		2 58.0	29.35
Thur.	9	22 47 03.7	15.08	16 15.97	71	7 53.08	8 54.0		2 54.1	29.62
Fri.	10	22 52 52.2	13.96	16 16.08	71	7 26.20	8 50.1		2 50.2	29.88
Sat.	11	22 58 13.7	12.83	16 16.20	71	6 58.89	8 46.1		2 46.2	30.13
Sun.	12	23 03 07.9	11.69	16 16.30	71	6 31.15	8 42.2		2 42.3	30.37
Mon.	13	23 07 34.6	10.54	16 16.41	71	6 03.03	8 38.2		2 38.3	30.61
Tues.	14	23 11 33.8	9.39	16 16.51	71	5 34.57	8 34.3		2 34.4	30.86
Wed.	15	23 15 05.1	8.23	16 16.60	71	5 05.78	8 30.4		2 30.4	31.13
Thur.	16	23 18 08.6	7.06	16 16.70	71	4 36.72	8 26.4		2 26.5	31.40
Fri.	17	23 20 44.1	5.89	16 16.78	71	4 07.42	8 22.5		2 22.5	31.69
Sat.	18	23 22 51.5	4.72	16 16.87	71	3 37.90	8 18.5		2 18.6	31.98
Sun.	19	23 24 30.8	3.55	16 16.95	71	3 08.22	8 14.6		2 14.6	32.27
Mon.	20	23 25 41.9	2.38	16 17.02	71	2 38.41	8 10.6		2 10.7	32.55
Tues.	21	23 26 24.8	1.20	16 17.10	71	2 08.51	8 06.7		2 06.7	32.82
Wed.	22	23 26 39.3	− 0.02	16 17.17	71	1 38.55	8 02.7		2 02.8	33.06
Thur.	23	23 26 25.6	+ 1.16	16 17.23	71	1 08.58	7 58.8		1 58.8	33.27
Fri.	24	23 25 43.5	2.34	16 17.29	71	0 38.64	7 54.8		1 54.9	33.47
Sat.	25	23 24 33.2	3.52	16 17.35	71	0 08.74	7 50.9		1 50.9	33.64
Sun.	26	23 22 54.6	4.69	16 17.40	71	0 21.06	7 46.9		1 47.0	33.81
Mon.	27	23 20 47.9	5.86	16 17.45	71	0 50.73	7 43.0		1 43.0	33.98
Tues.	28	23 18 13.1	7.03	16 17.49	71	1 20.25	7 39.0		1 39.1	34.17
Wed.	29	23 15 10.3	8.20	16 17.52	71	1 49.58	7 35.1		1 35.1	34.38
Thur.	30	23 11 39.5	9.36	16 17.55	71	2 18.70	7 31.1		1 31.2	34.61
Fri.	31	23 07 40.9	10.52	16 17.57	71	2 47.58	7 27.2		1 27.2	34.84
Sat.	32	S23 03 14.6	+11.67	16 17.58	71	3 16.18	7 23.2 P.M.	W.E.	1 23.3 A.M.	35.06

The sign + prefixed to the hourly change of declination indicates that { north / south } declinations are { increasing. / decreasing. }

The sign − prefixed to the hourly change of declination indicates that { south / north } declinations are { increasing. / decreasing. }

Serial Number this list	No. from Nautical Almanac	Constellation Name	North Declination			South Declination		
			R.A.	Decl.	Mag.	R.A.	Decl.	Mag.
			h m	°		h m	°	
1	1	α Andromedae (Alpheratz)	0 07	+29	2.1			
2 x X		β Hydri				0 24	−77	2.9
3	4	β Ceti (Diphda)				0 42	−18	2.2
4 E		α Ursae Minoris (Polaris)	2 04	+89	2.1			
5	6	α Arietis (Hamal)	2 06	+23	2.2			
6	10	α Tauri (Aldebaran)	4 34	+16	1.1			
7	11	β Orionis (Rigel)				5 13	− 8	0.3
8	12	α Aurigae (Capella)	5 15	+46	0.2			
9	16	α Orionis (Betelgeuse)	5 54	+ 7	0.5 v			
10 x	17	α Carinae (Canopus)				6 23	−53	−0.9
11	18	α Canis Majoris (Sirius)				6 44	−17	−1.6
12	20	α Canis Minoris (Procyon)	7 38	+ 5	0.5			
13	21	β Geminorum (Pollux)	7 44	+28	1.2			
14	25	α Hydrae (Alphard)				9 26	− 9	2.2
15	26	α Leonis (Regulus)	10 07	+12	1.3			
16	28	β Leonis (Denebola)	11 48	+15	2.2			
17	33	α Virginis (Spica)				13 24	−11	1.2
18 x	36	θ Centauri (Menkent)				14 05	−36	2.3
19	37	α Bootis (Arcturus)	14 14	+19	0.2			
20	41	α Coronae Borealis (Alphecca)	15 33	+27	2.3			
21 x	42	α Scorpii (Antares)				16 28	−26	1.2
22	46	α Ophiuchi (Rasalhague)	17 34	+13	2.1			
23	49	α Lyrae (Vega)	18 36	+39	0.1			
24 x	50	σ Sagittarii (Nunki)				18 53	−26	2.1
25	51	α Aquilae (Altair)	19 49	+ 9	0.9			
26	54	ε Pegasi (Enif)	21 43	+10	2.5			
27 x	56	α Piscis Australis (Fomalhaut)				22 56	−30	1.3
28	57	α Pegasi (Markab)	23 03	+15	2.6			

x: Required for stations south of 30° north latitude.
X: South circumpolar; not included in principal list of stars, Nautical Almanac.
E: Tabulated in this Ephemeris for daily position, including elongation.
v: Varies from 0.1 to 1.2 in magnitude or brilliancy.

α: Alpha. β: Beta. ε: Epsilon. θ: Theta. σ: Sigma. These designations are in the order of brightness, each within its own constellation.

The planets and the bright stars Capella, Canopus, and Vega, are tabulated as an aid in finding stellar positions.

For the south circumpolar star, No. 2 " β Hydri ", the horizontal angles, and the hour angle at elongation, may be found by the following equations (the lat. and decl. being treated as positive):

At elongation: $\cos t = \cot \delta \tan \varphi$; and, $\sin A = \dfrac{\cos \delta}{\cos \varphi}$

At any hour angle: $$\tan A = \frac{\sin t}{\cos \varphi \tan \delta - \sin \varphi \cos t}$$

The product " $\sin \varphi \cos t$ " is subtracted for hour angles 0° to 90°; added for hour angles 90° to 180°.
The hour angle " t " in these equations is in sidereal rate; conversions page 27.

STAR TABLES, MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME

No.	Mag.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit: Subtract for day of month	
		Jan. 1		Jan. 16		Feb. 1		Feb. 16			
		h m	° ′	h m	′	h m	′	h m	′		m
1– 1	2.1	5 24.1 P M	+28 56.0	4 25.1 P M	56.0	3 22.2 P M	56.0	2 23.2 P M	55.9	1	0.0
2	2.9	5 41.4	–77 25.3	4 42.4	25.3	3 39.5	25.2	2 40.5	25.1	2	3.9
3– 4	2.2	5 59.2	–18 08.8	5 00.2	08.8	3 57.3	08.8	2 58.3	08.8	3	7.9
4	2.1	7 21.2	+89 08.3	6 21.9	08.3	5 18.6	08.3	4 19.3	08.3	4	11.8
5– 6	2.2	7 22.4 [4]	+23 19.8	6 23.4 [4]	19.8	5 20.5 [4]	19.8	4 21.5 [4]	19.7	5	15.7
6–10	1.1	9 50.7	+16 27.3	8 51.7	27.3	7 48.8	27.3	6 49.9	27.3	6	19.7
7–11	0.3	10 29.5	– 8 14.0	9 30.5	14.0	8 27.6	14.0	7 28.6	14.0	7	23.6
8–12	0.2	10 30.9	+45 58.4	9 31.9	58.5	8 29.0	58.5	7 30.0	58.5	8	27.5
9–16	0.5 v	11 09.9	+ 7 24.3	10 10.9	24.3	9 08.0	24.2	8 09.0	24.2	9	31.5
10–17	–0.9	11 39.5 P M	–52 40.7	10 40.5	40.8	9 37.6	40.8	8 38.6	40.9	10	35.4
11–18	–1.6	{ 0 03.9 A M 11 59.9 P M }	–16 40.5	11 01.0	40.5	9 58.1	40.6	8 59.1	40.6	11	39.3
12–20	0.5	0 57.7 A M	+ 5 18.1	11 54.8 P M	18.0	10 51.9	18.0	9 52.9	18.0	12	43.2
Jan. 15		{ 0 02.6 A M 11 58.7 P M }								13	47.2
13–21	1.2	1 03.4 A M	+28 05.9	0 04.5 A M	05.9	10 57.6 P M	05.9	9 58.6	05.9	14	51.1
Jan. 17				{ 0 00.5 A M 11 56.6 P M }						15	55.0
14–25	2.2	2 45.8	– 8 31.9	1 46.8 A M	32.0	0 43.9 A M	32.0	11 41.0 P M	32.1	16	0.0
Feb. 12						{ 0 00.6 A M 11 56.7 P M }				17	3.9
15–26	1.3	3 26.3	+12 06.5	2 27.3	06.5	1 24.4 A M	06.4	0 25.5 A M	06.4	18	7.9
Feb. 22								{ 0 01.9 A M 11 57.9 P M }		19	11.8
16–28	2.2	5 06.8	+14 43.9	4 07.8	43.8	3 04.9	43.8	2 05.9 A M	43.8	20	15.7
17–33	1.2	6 42.6	–11 00.7	5 43.6	00.7	4 40.7	00.8	3 41.8	00.8	21	19.7
18–36	2.3	7 23.8	–36 13.6	6 24.8	13.7	5 21.9	13.7	4 22.9	13.8	22	23.6
19–37	0.2	7 33.1	+19 19.7	6 34.2	19.7	5 31.3	19.6	4 32.3	19.6	23	27.5
20–41	2.3	8 52.0	+26 48.4	7 53.1	48.4	6 50.2	48.3	5 51.2	48.3	24	31.5
21–42	1.2	9 46.0 [1,3]	–26 22.2	8 47.1 [1,2,3]	22.2	7 44.2 [1,2,3]	22.2	6 45.2 [2,3]	22.3	25	35.4
22–46	2.1	10 51.8	+12 34.6	9 52.8	34.6	8 49.9	34.5	7 51.0	34.5	26	39.3
23–49	0.1	11 54.0 A M	+38 45.2	10 55.0	45.1	9 52.1	45.1	8 53.2	45.0	27	43.2
24–50	2.1	12 11.5 P M	–26 20.2	11 12.5 A M	20.2	10 09.6 [1]	20.2	9 10.6 [1]	20.2	28	47.2
25–51	0.9	1 07.2	+ 8 47.4	12 08.3 P M	47.3	11 05.3 A M	47.3	10 06.4	47.2	29	51.1
26–54	2.5	3 00.3	+ 9 44.5	2 01.3	44.5	12 58.4 P M	44.4	11 59.5 A M	44.4	30	55.0
27–56	1.3	4 13.4	–29 46.7	3 14.4	46.7	2 11.5	46.7	1 12.5 P M	46.7	31	59.0
28–57	2.6	4 20.7 P M	+15 03.1	3 21.7 P M	03.0	2 18.8 P M	03.0	1 19.8 P M	02.9		
[1] Venus	–4.0	8 53 A M	–15°	8 50 A M	–18°	8 57 A M	–20°	9 08 A M	–21°		
[2] Mars	1.4	8 15 A M	–16°	7 54 A M	–18°	7 33 A M	–21°	7 13 A M	–22°		
[3] Jupiter	–1.5	9 01 A M	–19°	8 13 A M	–19°	7 20 A M	–20°	6 29 A M	–20°		
[4] Saturn	0.4	8 13 P M	+14°	7 13 P M	+14°	6 11 P M	+14°	5 15 P M	+15°		

Footnotes indicate near proximity of a planet to a star in time of transit and declination.

For time of transit subsequent to a star's double transit and until the next tabulated date, subtract for the number of days counting from the second transit of that date. All other interpolations may be taken directly by reference to the day of the month.

STAR TABLES, MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME

No.	Mag	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit	
		Mar. 1		Mar 16		Apr. 1		Apr. 16		Subtract for day of month	
		h m	° ′	h m	′	h m	′	h m	′		m
1– 1	2.1	1 32.1 P M	+28 55.9	12 33.1 P M	55.9	11 30.2 A M	55.8	10 31.2 A M	55.8	1	0.0
2	2.9	1 49.4	–77 25.1	12 50.4	25.0	11 47.5 A M	24.9	10 48.5	24.8	2	3.9
3– 4	2.2	2 07.2	–18 08.8	1 08.3	08.7	12 05.3 P M	08.7	11 06.4 A M	08.6	3	7.9
4	2.1	3 28.0	+89 08.3	2 28.7	08.2	1 25.7	08.2	12 26.7 P M	08.1	4	11.8
5– 6	2.2	3 30.4 [4]	+23 19.7	2 31.4 [4]	19.7	1 28.5 [4]	19.7	12 29.5 [4]	19.7	5	15.7
6–10	1.1	5 58.7	+16 27.3	4 59.8	27.3	3 56.8	27.3	2 57.9 [4]	27.3	6	19.7
7–11	0.3	6 37.5	– 8 14.1	5 38.5	14.1	4 35.6	14.1	3 36.6	14.0	7	23.6
8–12	0.2	6 38.9	+45 58.5	5 39.9	58.5	4 37.0	58.5	3 38.0	58.5	8	27.5
9–16	0.5 v	7 17.9	+ 7 24.2	6 18.9	24.2	5 16.0	24.2	4 17.0	24.2	9	31.5
10–17	–0.9	7 47.5	–52 40.9	6 48.5	41.0	5 45.6	41.0	4 46.6	41.0	10	35.4
11–18	–1.6	8 08.0	–16 40.6	7 09.0	40.7	6 06.1	40.7	5 07.1	40.7	11	39.3
12–20	0.5	9 01.8	+ 5 18.0	8 02.8	18.0	6 59.9	18.0	6 00.9	18.0	12	43.2
13–21	1.2	9 07.5	+28 05.9	8 08.5	05.9	7 05.6	05.9	6 06.7	05.9	13	47.2
14–25	2.2	10 49.9	– 8 32.1	9 50.9	32.1	8 48.0	32.1	7 49.0	32.1	14	51.1
15–26	1.3	11 30.4 P M	+12 06.4	10 31.4 P M	06.4	9 28.5	06.4	8 29.6	06.4	15	55.0
16–28	2.2	1 14.8 A M	+14 43.8	0 15.9 A M	43.8	11 09.0 P M	43.8	10 10.0	43.8	16	0.0
Mar. 20				{ 0 00.1 A M 11 56.2 P M }						17	3.9
17–33	1.2	2 50.6	–11 00.9	1 51.7 A M	00.9	0 48.8 A M	00.9	11 45.9 P M	00.9	18	7.9
Apr. 13						{ 0 01.6 A M 11 57.7 P M }				19	11.8
18–36	2.3	3 31.8	–36 13.8	2 32.9	13.9	1 30.0 A M	13.9	0 31.0 A M	14.0	20	15.7
Apr. 23								{ 0 03.5 A M 11 59.5 P M }		21	19.7
19–37	0.2	3 41.2	+19 19.6	2 42.2	19.6	1 39.3	19.6	0 40.3 A M	19.6	22	23.6
Apr. 26								{ 0 01.0 A M 11 57.1 P M }		23	27.5
20–41	2.3	5 00.1	+26 48.3	4 01.1	48.3	2 58.2	48.3	1 59.2 A M	48.3	24	31.5
21–42	1.2	5 54.1 [2,3]	–26 22.3	4 55.1 [3]	22.3	3 52.2 [3]	22.3	2 53.3 [3]	22.3	25	35.4
22–46	2.1	6 59.9	+12 34.5	6 00.9	34.5	4 58.0	34.5	3 59.0	34.5	26	39.3
23–49	0.1	8 02.0	+38 45.0	7 03.1	44.9	6 00.2	44.9	5 01.2	44.9	27	43.2
24–50	2.1	8 19.5 [1]	–26 20.1	7 20.6 [2]	20.1	6 17.7 [2]	20.1	5 18.7 [2]	20.1	28	47.2
25–51	0.9	9 15.3	+ 8 47.2	8 16.3	47.2	7 13.4	47.2	6 14.4	47.2	29	51.1
26–54	2.5	11 08.3 A M	+ 9 44.4	10 09.4	44.4	9 06.5	44.4	8 07.5	44.4	30	55.0
27–56	1.3	12 21.4 P M	–29 46.6	11 22.5	46.6	10 19.6	46.5	9 20.6	46.5	31	59.0
28–57	2.6	12 28.7 P M	+15 02.9	11 29.7 A M	02.9	10 26.8 A M	02.9	9 27.8 A M	02.9		
[1] Venus	–3.5	9 20 A M	–20°	9 34 A M	–16°	9 46 A M	–11°	9 55 A M	– 5°		
[2] Mars	0.6	6 57 A M	–23°	6 37 A M	–24°	6 16 A M	–23°	5 54 A M	–23°		
[3] Jupiter	–1.9	5 42 A M	–20°	4 46 A M	–20°	3 43 A M	–20°	2 41 A M	–20°		
[4] Saturn	0.4	4 27 P M	+15°	3 33 P M	+15°	2 36 P M	+16°	1 44 P M	+16°		

Footnotes indicate near proximity of a planet to a star in time of transit and declination.

For reduction of time of transit from the Greenwich mean time to the local mean time at the longitude of the station, see table of Sidereal Conversions, page 27

STAR TABLES, MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME

No.	Mag.	Transit (May 1)	Decl. (May 1)	Transit (May 16)	Decl. (May 16)	Transit (June 1)	Decl. (June 1)	Transit (June 16)	Decl. (June 16)	Transit: Subtract for day of month	
		h m	° ′	h m	′	h m	′	h m	′		m
1– 1	2.1	9 32.2 A M	+28 55.8	8 33.3 A M	55.8	7 30.4 A M	55.8	6 31.4 A M	55.9	1	0.0
2	2.9	9 49.5	–77 24.7	8 50.6	24.6	7 47.7	24.5	6 48.7	24.5	2	3.9
3– 4	2.2	10 07.4	–18 08.6	9 08.4	08.5	8 05.5	08.5	7 06.6	08.4	3	7.9
4	2.1	11 27.7	+89 08.0	10 28.9	07.9	9 26.2	07.9	8 27.6	07.8	4	11.8
5– 6	2.2	11 30.6 A M	+23 19.7	10 31.6 A M	19.7	9 28.7 [1]	19.7	8 29.7	19.7	5	15.7
6–10	1.1	1 58.9 P M [4]	+16 27.3	12 59.9 P M [4]	27.3	11 57.0 A M [4]	27.3	10 58.0 [1] [4]	27.3	6	19.7
7–11	0.3	2 37.7	– 8 14.0	1 38.7	14.0	12 35.8 P M	13.9	11 36.8	13.9	7	23.6
8–12	0.2	2 39.1	+45 58.4	1 40.1	58.4	12 37.2	58.4	11 38.2 A M	58.3	8	27.5
9–16	0.5 v	3 18.0	+ 7 24.2	2 19.0	24.2	1 16.1	24.3	12 17.2 P M	24.3	9	31.5
10–17	–0.9	3 47.6	–52 40.9	2 48.6	40.9	1 45.7	40.8	12 46.7	40.7	10	35.4
11–18	–1.6	4 08.1	–16 40.6	3 09.2	40.6	2 06.3	40.6	1 07.3	40.5	11	39.3
12–20	0.5	5 01.9	+ 5 18.0	4 02.9	18.0	3 00.0	18.0	2 01.1	18.0	12	43.2
13–21	1.2	5 07.7	+28 05.9	4 08.7	05.9	3 05.8	05.9	2 06.8	05.9	13	47.2
14–25	2.2	6 50.0	– 8 32.1	5 51.0	32.1	4 48.1	32.1	3 49.1	32.1	14	51.1
15–26	1.3	7 30.6	+12 06.4	6 31.6	06.5	5 28.7	06.5	4 29.7	06.5	15	55.0
16–28	2.2	9 11.1	+14 43.8	8 12.1	43.9	7 09.2	43.9	6 10.2	43.9	16	0.0
17–33	1.2	10 46.9	–11 01.0	9 47.9	01.0	8 45.0	01.0	7 46.0	00.9	17	3.9
18–36	2.3	11 28.1	–36 14.0	10 29.1	14.1	9 26.2	14.1	8 27.2	14.1	18	7.9
19–37	0.2	11 37.4 P M	+19 19.7	10 38.4 P M	19.7	9 35.5	19.7	8 36.6	19.8	19	11.8
20–41	2.3	1 00.3 A M	+26 48.4	{ 0 01.3 A M 11 57.4 P M }	48.4	10 54.4	48.5	9 55.5	48.5	20	15.7
21–42	1.2	1 54.3 [3]	–26 22.4	0 55.3 A M [3]	22.4	11 48.5 P M [3]	22.4	10 49.5 [3]	22.4	21	19.7
May 30				{ 0 00.3 A M 11 56.3 P M }						22	23.6
22–46	2.1 -	3 00.1	+12 34.5	2 01.1 A M	34.6	0 58.2 A M	34.6	11 55.3 P M	34.7	23	27.5
June 15						{ 0 03.1 A M 11 59.2 P M }				24	31.5
23–49	0.1	4 02.2	+38 45.0	3 03.3	45.1	2 00.4 A M	45.1	1 01.4 A M	45.2	25	35.4
24–50	2.1	4 19.7 [2]	–26 20.1	3 20.7	20.1	2 17.8	20.1	1 18.9	20.1	26	39.3
25–51	0.9	5 15.5	+ 8 47.3	4 16.5	47.3	3 13.6	47.4	2 14.6	47.4	27	43.2
26–54	2.5	7 08.5	+ 9 44.4	6 09.6	44.4	5 06.7	44.5	4 07.7	44.5	28	47.2
27–56	1.3	8 21.6	–29 46.4	7 22.6	46.3	6 19.7	46.3	5 20.8	46.2	29	51.1
28–57	2.6	8 28.8 A M	+15 02.9	7 29.9 A M	02.9	6 27.0 A M	03.0	5 28.0 A M	03.0	30	55.0
										31	59.0

Planet	Mag.	May 1 Transit	Decl.	May 16 Transit	Decl.	June 1 Transit	Decl.	June 16 Transit	Decl.
[1] Venus	–3.3	10 02 A M	+ 2°	10 11 A M	+ 9°	10 22 A M	+15°	10 37 A M	+20°
[2] Mars	–0.8	5 30 A M	–22°	5 03 A M	–21°	4 30 A M	–20°	3 52 A M	–19°
[3] Jupiter	–2.1	1 37 A M	–20°	0 30 A M	–20°	11 15 P M	–19°	10 09 P M	–19°
[4] Saturn	0.4	12 53 P M	+17°	12 02 P M	+17°	11 07 A M	+18°	10 16 A M	+18°

Footnotes indicate near proximity of a planet to a star in time of transit and declination.

For time of transit subsequent to a star's double transit and until the next tabulated date, subtract for the number of days counting from the second transit of that date. All other interpolations may be taken directly by reference to the day of the month.

STAR TABLES, MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME

No.	Mag.	Transit July 1	Decl. July 1	Transit July 16	Decl. July 16	Transit Aug 1	Decl. Aug 1	Transit Aug 16	Decl. Aug 16	Transit: Subtract for day of month	
		h m	° ′	h m	′	h m	′	h m	′		m
1– 1	2.1	5 32.4 AM	+28 55.9	4 33.5 AM	56.0	3 30.6 AM	56.0	2 31.6 AM	56.1	1	0.0
2	2.9	5 49.8	–77 24.5	4 50.8	24.4	3 47.9	24.5	2 49.0	24.5	2	3.9
3– 4	2.2	6 07.6	–18 08.3	5 08.6	08.3	4 05.7	08.3	3 06.7	08.2	3	7.9
4	2.1	7 28.9	+89 07.8	6 30.3	07.8	5 27.8	07.8	4 29.2	07.9	4	11.8
5– 6	2.2	7 30.7	+23 19.7	6 31.8	19.8	5 28.9	19.8	4 29.9	19.9	5	15.7
6–10	1.1	9 59.1 [4]	+16 27.3	9 00.1 [4]	27.3	7 57.2 [4]	27.3	6 58.2 [4]	27.4	6	19.7
7–11	0.3	10 37.8	– 8 13.9	9 38.9	13.8	8 36.0	13.8	7 37.0	13.7	7	23.6
8–12	0.2	10 39.2	+45 58.3	9 40.3	58.3	8 37.4	58.3	7 38.4	58.3	8	27.5
9–16	0.5v	11 18.2	+ 7 24.3	10 19.2	24.3	9 16.3	24.4	8 17.3	24.4	9	31.5
10–17	–0.9	11 47.8 AM	–52 40.7	10 48.8	40.6	9 45.9	40.5	8 46.9	40.4	10	35.4
11–18	–1.6	12 08.3 PM	–16 40.5	11 09.3 AM	40.4	10 06.4	40.4	9 07.4	40.3	11	39.3
12–20	0.5	1 02.1	+ 5 18.0	12 03.1 PM	18.1	11 00.2	18.1	10 01.2	18.1	12	43.2
13–21	1.2	1 07.8	+28 05.9	12 08.8 [1]	05.9	11 05.9 AM [1]	05.9	10 07.0	05.9	13	47.2
14–25	2.2	2 50.2	– 8 32.1	1 51.2	32.0	12 48.3 PM	32.0	11 49.3 AM	32.0	14	51.1
15–26	1.3	3 30.7	+12 06.5	2 31.7	06.5	1 28.8	06.5	12 29.9 PM [1]	06.5	15	55.0
16–28	2.2	5 11.2	+14 43.9	4 12.2	43.9	3 09.3	43.9	2 10.3	43.9	16	0.0
17–33	1.2	6 47.0	–11 00.9	5 48.1	00.9	4 45.1	00.9	3 46.2	00.9	17	3.9
18–36	2.3	7 28.2	–36 14.1	6 29.3	14.1	5 26.3	14.1	4 27.4	14.1	18	7.9
19–37	0.2	7 37.6	+19 19.8	6 38.6	19.8	5 35.7	19.8	4 36.7	19.8	19	11.8
20–41	2.3	8 56.5	+26 48.6	7 57.5	48.6	6 54.6	48.6	5 55.6	48.7	20	15.7
21–42	1.2	9 50.5 [3]	–26 22.4	8 51.5 [3]	22.4	7 48.6 [3]	22.4	6 49.6 [3]	22.4	21	19.7
22–46	2.1	10 56.3 PM	+12 34.7	9 57.3	34.8	8 54.4	34.8	7 55.4	34.8	22	23.6
23–49	0.1	{ 0 02.4 AM 11 58.5 PM }	+38 45.3	10 59.5	45.4	9 56.6	45.5	8 57.6	45.5	23	27.5
24–50	2.1	0 19.9 AM	–26 20.1	11 17.0 PM	20.1	10 14.1	20.1	9 15.1	20.1	24	31.5
July 6		{ 0 00.2 AM 11 56.3 PM }								25	35.4
25–51	0.9	1 15.6 AM	+ 8 47.5	0 16.7 AM	47.5	11 09.8 PM	47.6	10 10.8 PM	47.6	26	39.3
July 20				{ 0 00.9 AM 11 57.0 PM }						27	43.2
26–54	2.5	3 08.7	+ 9 44.6	2 09.7 AM	44.7	1 06.8 AM	44.7	0 07.9 AM	44.8	28	47.2
Aug. 17								{ 0 03.9 AM 11 59.9 PM }		29	51.1
27–56	1.3	4 21.8 [2]	–29 46.2	3 22.8 [2]	46.2	2 19.9	46.2	1 21.0 AM	46.2	30	55.0
28–57	2.6	4 29.0 AM	+15 03.1	3 30.1 AM	03.1	2 27.2 AM	03.2	1 28.2 AM	03.3	31	59.0

Planet	Mag.	July 1		July 16		Aug 1		Aug 16	
[1] Venus	–3.4	10 56 AM	+23°	11 16 AM	+23°	11 37 AM	+21°	11 54 AM	+16°
[2] Mars	–2.3	3 07 AM	–19°	2 12 AM	–20°	1 00 AM	–21°	11 41 PM	–23°
[3] Jupiter	–1.8	9 04 PM	–19°	8 02 PM	–19°	6 59 PM	–19°	6 03 PM	–19°
[4] Saturn	0.4	9 24 AM	+19°	8 31 AM	+19°	7 35 AM	+19°	6 40 AM	+19°

Footnotes indicate near proximity of a planet to a star in time of transit and declination.

For reduction of time of transit from the Greenwich mean time to the local mean time at the longitude of the station, see table of Sidereal Conversions, page 27.

STAR TABLES, MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME

No.	Mag.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit Subtract for day of month	
		Sept. 1		Sept. 16		Oct. 1		Oct. 16			
		h m	° ′	h m	′	h m	′	h m	′		m
1– 1	2.1	1 28.7 AM	+28 56.2	0 29.7 AM	56.2	11 26.8 PM	56.3	10 27.8 PM	56.3	1	0.0
Sept. 23				{0 02.2 AM 11 58.3 PM}						2	3.9
2	2.9	1 46.1	−77 24.5	0 47.1 AM	24.6	11 44.2 PM	24.7	10 45.2	24.8	3	7.9
Sept. 27				{0 03.9 AM 11 59.9 PM}						4	11.8
3– 4	2.2	2 03.8	−18 08.2	1 04.9 AM	08.2	0 05.9 AM	08.3	11 03.0 PM	08.3	5	15.7
Oct. 2						{0 02.0 AM 11 58.0 PM}				6	19.7
4	2.1	3 26.7	+89 07.9	2 28.0	08.0	1 29.2 AM	08.1	0 30.4 AM	08.2	7	23.6
Oct. 23								{0 03.0 AM 11 59.0 PM}		8	27.5
5– 6	2.2	3 27.0	+23 19.9	2 28.0	19.9	1 29.1	20.0	0 30.1 AM	20.0	9	31.5
Oct. 23								{0 02.6 AM 11 58.6 PM}		10	35.4
6–10	1.1	5 55.3 [4]	+16 27.4	4 56.3 [4]	27.4	3 57.4 [4]	27.4	2 58.4 AM [4]	27.4	11	39.3
7–11	0.3	6 34.1	− 8 13.7	5 35.1	13.7	4 36.1	13.7	3 37.2	13.7	12	43.2
8–12	0.2	6 35.5	+45 58.3	5 36.5	58.3	4 37.6	58.3	3 38.6	58.3	13	47.2
9–16	0.5 v	7 14.4	+ 7 24.4	6 15.5	24.4	5 16.5	24.4	4 17.5	24.4	14	51.1
10–17	−0.9	7 44.0	−52 40.4	6 45.0	40.4	5 46.1	40.3	4 47.1	40.4	15	55.0
11–18	−1.6	8 04.5	−16 40.3	7 05.6	40.3	6 06.6	40.3	5 07.6	40.3	16	0.0
12–20	0.5	8 58.3	+ 5 18.1	7 59.3	18.1	7 00.4	18.1	6 01.4	18.1	17	3.9
13–21	1.2	9 04.1	+28 05.8	8 05.1	05.8	7 06.1	05.8	6 07.2	05.8	18	7.9
14–25	2.2	10 46.4	− 8 32.0	9 47.4	32.0	8 48.4	32.0	7 49.5	32.0	19	11.8
15–26	1.3	11 27.0 AM [1]	+12 06.5	10 28.0 AM	06.5	9 29.0	06.4	8 30.0	06.4	20	15.7
16–28	2.2	1 07.4 PM [1]	+14 43.9	12 08.5 PM	43.9	11 09.5 AM	43.8	10 10.5	43.8	21	19.7
17–33	1.2	2 43.3	−11 00.9	1 44.3	00.9	12 45.3 PM [1]	00.9	11 46.3 AM [1]	00.9	22	23.6
18–36	2.3	3 24.4	−36 14.1	2 25.5	14.0	1 26.5	14.0	12 27.5 PM	14.0	23	27.5
19–37	0.2	3 33.8	+19 19.8	2 34.8	19.8	1 35.8	19.8	12 36.9	19.7	24	31.5
20–41	2.3	4 52.7	+26 48.7	3 53.7	48.6	2 54.7	48.6	1 55.8	48.6	25	35.4
21–42	1.2	5 46.7 [3]	−26 22.4	4 47.8 [3]	22.4	3 48.8 [3]	22.4	2 49.8 [3]	22.4	26	39.3
22–46	2.1	6 52.5	+12 34.8	5 53.5	34.8	4 54.5	34.8	3 55.6	34.8	27	43.2
23–49	0.1	7 54.7	+38 45.6	6 55.7	45.6	5 56.7	45.6	4 57.8	45.6	28	47.2
24–50	2.1	8 12.2	−26 20.1	7 13.2	20.1	6 14.2	20.1	5 15.3	20.1	29	51.1
25–51	0.9	9 07.9	+ 8 47.6	8 09.0	47.7	7 10.0	47.7	6 11.0	47.7	30	55.0
26–54	2.5	11 01.0 PM	+ 9 44.8	10 02.0	44.8	9 03.1	44.9	8 04.1	44.9	31	59.0
27–56	1.3	0 18.1 AM	−29 46.2	11 15.1	46.2	10 16.2	46.2	9 17.2	46.3		
Sept. 5		{0 02.3 AM 11 58.4 PM}									
28–57	2.6	0 25.3 AM	+15 03.3	11 22.4 PM	03.4	10 23.4 PM	03.4	9 24.4 PM	03.4		
Sept. 7		{0 01.7 AM 11 57.8 PM}									
[1] Venus	−3.4	12 07 PM	+ 9°	12 17 PM	+ 2°	12 26 PM	− 5°	12 37 PM	−13°		
[2] Mars	−1.5	10 25 PM	−23°	9 24 PM	−22°	8 36 PM	−20°	7 56 PM	−18°		
[3] Jupiter	−1.5	5 06 PM	−19°	4 15 PM	−20°	3 26 PM	−20°	2 38 PM	−21°		
[4] Saturn	0.1	5 40 AM	+19°	4 42 AM	+19°	3 43 AM	+19°	2 42 AM	+19°		

Footnotes indicate near proximity of a planet to a star in time of transit and declination.

For time of transit subsequent to a star's double transit and until the next tabulated date, subtract for the number of days counting from the second transit of that date. All other interpolations may be taken directly by reference to the day of the month.

STAR TABLES, MERIDIAN OF GREENWICH, CIVIL DATE AND MEAN TIME

No.	Mag.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit	Decl.	Transit	
		Nov. 1		Nov. 16		Dec. 1		Dec. 16		Subtract for day of month	
		h m	° ′	h m	′	h m	′	h m	′		m
1 – 1	2.1	9 24.9 P M	+28 56.4	8 25.9 P M	56.4	7 27.0 P M	56.4	6 28.0 P M	56.4	1	0.0
2	2.9	9 42.3	–77 24.8	8 43.3	24.9	7 44.3	24.9	6 45.3	25.0	2	3.9
3 – 4	2.2	10 00.1	–18 08.3	9 01.1	08.3	8 02.1	08.4	7 03.1	08.4	3	7.9
4	2.1	11 23.7	+89 08.3	10 24.7	08.4	9 25.6	08.4	8 26.4	08.5	4	11.8
5 – 6	2.2	11 23.3 P M	+23 20.0	10 24.3 P M	20.1	9 25.3	20.1	8 26.3	20.1	5	15.7
6 – 10	1.1	1 55.5 A M[4]	+16 27.4	0 56.5 A M[4]	27.4	11 53.6 P M[4]	27.4	10 54.6[4]	27.4	6	19.7
Nov. 30				{ 0 01.5 A M 11 57.5 P M }						7	23.6
7 – 11	0.3	2 34.3	– 8 13.7	1 35.3 A M	13.8	0 36.3 A M	13.8	11 33.4	13.9	8	27.5
Dec. 10						{ 0 00.9 A M 11 57.0 P M }				9	31.5
8 – 12	0.2	2 35.7	+45 58.3	1 36.7	58.3	0 37.8 A M	58.4	11 34.9 P M	58.4	10	35.4
Dec. 10						{ 0 02.4 A M 11 58.4 P M }				11	39.3
9 – 16	0.5 v	3 14.6	+ 7 24.4	2 15.6	24.3	1 16.7 A M	24.3	0 17.7 A M	24.3	12	43.2
Dec. 20								{ 0 02.0 A M 11 58.0 P M }		13	47.2
10 – 17	–0.9	3 44.2	–52 40.4	2 45.2	40.5	1 46.3	40.6	0 47.3 A M	40.6	14	51.1
Dec. 28								{ 0 00.1 A M 11 56.2 P M }		15	55.0
11 – 18	–1.6	4 04.7	–16 40.3	3 05.8	40.4	2 06.8	40.4	1 07.8 A M	40.5	16	0.0
12 – 20	0.5	4 58.5	+ 5 18.0	3 59.5	18.0	3 00.6	18.0	2 01.6	17.9	17	3.9
13 – 21	1.2	5 04.3	+28 05.7	4 05.3	05.7	3 06.3	05.7	2 07.4	05.7	18	7.9
14 – 25	2.2	6 46.6	– 8 32.0	5 47.6	32.0	4 48.6	32.1	3 49.7	32.1	19	11.8
15 – 26	1.3	7 27.1	+12 06.3	6 28.2	06.3	5 29.2	06.3	4 30.2	06.2	20	15.7
16 – 28	2.2	9 07.6	+14 43.7	8 08.6	43.7	7 09.7	43.6	6 10.7	43.6	21	19.7
17 – 33	1.2	10 43.4	–11 00.9	9 44.4	00.9	8 45.5	00.9	7 46.5	00.9	22	23.6
18 – 36	2.3	11 24.6	–36 13.9	10 25.6	13.9	9 26.7	13.9	8 27.7	13.9	23	27.5
19 – 37	0.2	11 33.9 A M	+19 19.7	10 35.0	19.6	9 36.0	19.5	8 37.0	19.5	24	31.5
20 – 41	2.3	12 52.8 P M	+26 48.5	11 53.9 A M	48.5	10 54.9	48.4	9 55.9	48.3	25	35.4
21 – 42	1.2	1 46.9[1][3]	–26 22.3	12 47.9 P M[1][3]	22.3	11 48.9 A M[3]	22.3	10 50.0[3]	22.3	26	39.3
22 – 46	2.1	2 52.7	+12 34.8	1 53.7	34.8	12 54.7 P M	34.7	11 55.7 A M	34.7	27	43.2
23 – 49	0.1	3 54.8	+38 45.6	2 55.9	45.5	1 56.9	45.5	12 57.9 P M	45.4	28	47.2
24 – 50	2.1	4 12.3	–26 20.1	3 13.4	20.1	2 14.4[1]	20.1	1 15.4[1]	20.1	29	51.1
25 – 51	0.9	5 08.1	+ 8 47.7	4 09.1	47.7	3 10.1	47.6	2 11.1	47.6	30	55.0
26 – 54	2.5	7 01.2	+ 9 44.9	6 02.2	44.9	5 03.2	44.9	4 04.2	44.8	31	59.0
27 – 56	1.3	8 14.3	–29 46.3	7 15.3	46.3	6 16.3	46.4	5 17.3	46.4		
28 – 57	2.6	8 21.5 P M	+15 03.4	7 22.5 P M	03.4	6 23.6 P M	03.4	5 24.6 P M	03.4		
[1] Venus	–3.3	12 53 P M	–19°	1 12 P M	–23°	1 34 P M	–25°	1 57 P M	–23°		
[2] Mars	0.0	7 21 P M	–15°	6 51 P M	–11°	6 24 P M	– 7°	5 59 P M	– 3°		
[3] Jupiter	–1.3	1 48 P M	–21°	1 03 P M	–22°	12 18 P M	–22°	11 34 A M	–23°		
[4] Saturn	–0.1	1 35 A M	+19°	0 31 A M	+19°	11 23 P M	+19°	10 19 P M	+18°		

Footnotes indicate near proximity of a planet to a star in time of transit and declination.

For reduction of time of transit from the Greenwich mean time to the local mean time at the longitude of the station, see table of Sidereal Conversions, page 27.

Mean Time Hour Angle	AZIMUTH OF POLARIS AT ALL HOUR ANGLES, 1971 — Mean Declination + 89°08′ 10″ — Latitude												CORR. TO AZIMUTH — Add for Decl. + 89°		
													8′00″	7′50″	7′40″
													Subtract for Decl. + 89°		
	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°		8′20″	8′30″	8′40″
h m	′	′	′	′	′	′	′	′	′	′	′		′	′	′
0 00.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
0 10.0	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	2.5	2.6	2.6		0.0	0.0	0.0
19.9	4.6	4.6	4.7	4.7	4.8	4.8	4.9	5.0	5.1	5.2	5.3		0.0	0.0	0.0
29.9	6.9	6.9	7.0	7.1	7.1	7.2	7.3	7.5	7.6	7.7	7.9		0.0	0.0	0.1
0 39.9	9.2	9.2	9.3	9.4	9.5	9.6	9.8	9.9	10.1	10.3	10.5		0.0	0.1	0.1
49.9	11.4	11.5	11.6	11.7	11.9	12.0	12.2	12.4	12.6	12.8	13.1		0.0	0.1	0.1
59.8	13.7	13.8	13.9	14.0	14.2	14.4	14.6	14.8	15.0	15.3	15.6		0.0	0.1	0.1
1 09.8	15.9	16.0	16.1	16.3	16.5	16.7	16.9	17.2	17.5	17.8	18.1		0.1	0.1	0.2
19.8	18.0	18.2	18.3	18.5	18.7	19.0	19.2	19.5	19.9	20.2	20.6		0.1	0.1	0.2
29.8	20.2	20.3	20.5	20.7	21.0	21.2	21.5	21.8	22.2	22.6	23.1		0.1	0.1	0.2
1 39.7	22.3	22.5	22.7	22.9	23.1	23.4	23.8	24.1	24.5	25.0	25.5		0.1	0.2	0.2
49.7	24.4	24.5	24.8	25.0	25.3	25.6	26.0	26.4	26.8	27.3	27.9		0.1	0.2	0.2
59.7	26.4	26.6	26.8	27.1	27.4	27.7	28.1	28.5	29.0	29.6	30.2		0.1	0.2	0.3
2 09.6	28.3	28.6	28.8	29.1	29.4	29.8	30.2	30.7	31.2	31.8	32.4		0.1	0.2	0.3
19.6	30.3	30.5	30.7	31.0	31.4	31.8	32.2	32.7	33.3	33.9	34.6		0.1	0.2	0.3
29.6	32.1	32.3	32.6	32.9	33.3	33.7	34.2	34.7	35.3	36.0	36.7		0.1	0.2	0.3
2 39.6	33.9	34.1	34.4	34.8	35.2	35.6	36.1	36.7	37.3	38.0	38.7		0.1	0.2	0.3
49.5	35.6	35.9	36.2	36.5	37.0	37.4	37.9	38.5	39.2	39.9	40.7		0.1	0.2	0.4
59.5	37.3	37.6	37.9	38.2	38.7	39.2	39.7	40.3	41.0	41.7	42.6		0.1	0.3	0.4
3 09.5	38.9	39.2	39.5	39.9	40.3	40.8	41.4	42.0	42.7	43.5	44.4		0.1	0.3	0.4
19.5	40.4	40.7	41.0	41.4	41.9	42.4	43.0	43.7	44.4	45.2	46.1		0.1	0.3	0.4
29.4	41.8	42.1	42.5	42.9	43.4	43.9	44.5	45.2	46.0	46.8	47.7		0.1	0.3	0.4
3 39.4	43.2	43.5	43.9	44.3	44.8	45.3	46.0	46.7	47.4	48.3	49.3		0.1	0.3	0.4
49.4	44.5	44.8	45.1	45.6	46.1	46.7	47.3	48.0	48.8	49.7	50.7		0.2	0.3	0.5
59.3	45.6	46.0	46.4	46.8	47.3	47.9	48.6	49.3	50.1	51.0	52.1		0.2	0.3	0.5
4 09.3	46.7	47.1	47.5	47.9	48.5	49.1	49.7	50.5	51.3	52.3	53.3		0.2	0.3	0.5
19.3	47.8	48.1	48.5	49.0	49.5	50.1	50.8	51.6	52.4	53.4	54.4		0.2	0.3	0.5
29.3	48.7	49.0	49.4	49.9	50.4	51.1	51.8	52.6	53.4	54.4	55.5		0.2	0.3	0.5
4 39.2	49.5	49.9	50.3	50.7	51.3	51.9	52.6	53.4	54.3	55.3	56.4		0.2	0.3	0.5
49.2	50.2	50.6	51.0	51.5	52.1	52.7	53.4	54.2	55.1	56.1	57.2		0.2	0.3	0.5
59.2	50.9	51.2	51.7	52.1	52.7	53.4	54.1	54.9	55.8	56.8	57.9		0.2	0.3	0.5
5 09.2	51.4	51.8	52.2	52.7	53.3	53.9	54.7	55.5	56.4	57.4	58.5		0.2	0.3	0.5
19.1	51.9	52.2	52.6	53.1	53.7	54.4	55.1	55.9	56.9	57.9	59.0		0.2	0.3	0.5
29.1	52.2	52.6	53.0	53.5	54.1	54.7	55.5	56.3	57.2	58.3	59.4		0.2	0.4	0.5
5 39.1	52.4	52.8	53.2	53.7	54.3	55.0	55.7	56.6	57.5	58.5	59.7		0.2	0.4	0.5
49.0	52.6	52.9	53.4	53.9	54.5	55.1	55.9	56.7	57.6	58.7	59.8		0.2	0.4	0.5
57.0	...	...	...	...	...	...	...	...	...	...	59.9		0.2	0.4	0.6
5 57.2	...	...	...	...	...	...	...	...	...	58.7	...		0.2	0.4	0.6
57.3	...	...	...	...	...	...	...	...	57.7	...	...		0.2	0.4	0.6
57.5	...	...	...	...	...	...	...	56.7	...	...	...		0.2	0.4	0.5
5 57.6	...	...	...	...	...	...	55.9	...	...	...	...		0.2	0.4	0.5
57.8	...	...	...	...	...	55.2	...	...	...	...	...		0.2	0.4	0.5
57.9	...	...	...	...	54.5	...	...	...	...	...	...		0.2	0.4	0.5
5 58.0	...	...	...	53.9	...	...	...	...	...	...	...		0.2	0.3	0.5
58.2	...	...	53.4	...	...	...	...	...	...	...	...		0.2	0.3	0.5
58.3	...	53.0	...	...	...	...	...	...	...	...	...		0.2	0.3	0.5
5 58.4	52.6	...	...	...	...	...	...	...	...	...	...		0.2	0.3	0.5

See footnote pages 18 and 19 for equation to be employed when values in seconds are required.

Mean Time Hour Angle	AZIMUTH OF POLARIS AT ALL HOUR ANGLES, 1971 — Mean Declination + 89°08′ 10″ — Latitude												CORR. TO AZIMUTH — Add for Decl. + 89° 8′00″ / Subtract for Decl. + 89° 8′20″	Add 7′50″ / Subtract 8′30″	Add 7′40″ / Subtract 8′40″
	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°				
h m	′	′	′	′	′	′	′	′	′	′	′		′	′	′
5 57.0	...	...	...	...	...	...	...	...	...	...	59.9		0.2	0.4	0.6
57.2	...	...	...	...	...	...	...	...	...	58.7	...		0.2	0.4	0.6
57.3	...	...	...	...	...	...	...	...	57.7	...	...		0.2	0.4	0.6
5 57.5	...	...	...	...	...	...	...	56.7	...	...	...		0.2	0.4	0.5
57.6	...	...	...	...	...	...	55.9	...	...	...	...		0.2	0.4	0.5
57.8	...	...	...	...	...	55.2	...	...	...	...	...		0.2	0.4	0.5
5 57.9	...	...	...	...	54.5	...	...	...	...	...	...		0.2	0.4	0.5
58.0	...	...	...	53.9	...	...	...	...	...	...	...		0.2	0.3	0.5
58.2	...	...	53.4	...	...	...	...	...	...	...	...		0.2	0.3	0.5
5 58.3	...	53.0	...	...	...	...	...	...	...	...	...		0.2	0.3	0.5
58.4	52.6	...	...	...	...	...	...	...	...	...	...		0.2	0.3	0.5
59.0	52.6	53.0	53.4	53.9	54.5	55.2	55.9	56.7	57.7	58.7	59.9		0.2	0.4	0.5
6 09.0	52.6	52.9	53.4	53.9	54.4	55.1	55.8	56.7	57.6	58.6	59.8		0.2	0.4	0.5
19.0	52.4	52.8	53.2	53.7	54.3	54.9	55.7	56.5	57.4	58.4	59.6		0.2	0.4	0.5
28.9	52.2	52.5	52.9	53.4	54.0	54.6	55.4	56.2	57.1	58.1	59.3		0.2	0.4	0.5
6 38.9	51.8	52.2	52.6	53.1	53.6	54.3	55.0	55.8	56.7	57.7	58.9		0.2	0.3	0.5
48.9	51.4	51.7	52.1	52.6	53.2	53.8	54.5	55.3	56.2	57.2	58.3		0.2	0.3	0.5
58.9	50.8	51.1	51.5	52.0	52.6	53.2	53.9	54.7	55.6	56.6	57.7		0.2	0.3	0.5
7 08.8	50.2	50.5	50.9	51.4	51.9	52.5	53.2	54.0	54.9	55.9	56.9		0.2	0.3	0.5
18.8	49.4	49.7	50.1	50.6	51.1	51.7	52.4	53.2	54.1	55.0	56.1		0.2	0.3	0.5
28.8	48.6	48.9	49.3	49.7	50.3	50.9	51.5	52.3	53.1	54.1	55.1		0.2	0.3	0.5
7 38.7	47.6	48.0	48.3	48.8	49.3	49.9	50.5	51.3	52.1	53.0	54.0		0.2	0.3	0.5
48.7	46.6	46.9	47.3	47.7	48.2	48.8	49.4	50.2	51.0	51.9	52.9		0.2	0.3	0.5
58.7	45.5	45.8	46.2	46.6	47.1	47.6	48.3	49.0	49.8	50.6	51.6		0.2	0.3	0.5
8 08.7	44.3	44.6	45.0	45.4	45.8	46.4	47.0	47.7	48.4	49.3	50.2		0.1	0.3	0.4
18.6	43.0	43.3	43.7	44.1	44.5	45.0	45.6	46.3	47.0	47.9	48.8		0.1	0.3	0.4
28.6	41.7	42.0	42.3	42.7	43.1	43.6	44.2	44.8	45.5	46.3	47.2		0.1	0.3	0.4
8 38.6	40.3	40.5	40.8	41.2	41.6	42.1	42.7	43.3	44.0	44.7	45.6		0.1	0.3	0.4
48.6	38.7	39.0	39.3	39.6	40.1	40.5	41.0	41.6	42.3	43.0	43.9		0.1	0.3	0.4
58.5	37.1	37.4	37.7	38.0	38.4	38.9	39.4	39.9	40.6	41.3	42.1		0.1	0.3	0.4
9 08.5	35.5	35.7	36.0	36.3	36.7	37.1	37.6	38.1	38.8	39.4	40.2		0.1	0.2	0.4
18.5	33.8	34.0	34.2	34.5	34.9	35.3	35.8	36.3	36.9	37.5	38.2		0.1	0.2	0.3
28.4	32.0	32.2	32.4	32.7	33.1	33.4	33.9	34.4	34.9	35.5	36.2		0.1	0.2	0.3
9 38.4	30.1	30.3	30.5	30.8	31.1	31.5	31.9	32.4	32.9	33.5	34.1		0.1	0.2	0.3
48.4	28.2	28.4	28.6	28.9	29.2	29.5	29.9	30.3	30.8	31.3	31.9		0.1	0.2	0.3
58.4	26.3	26.4	26.6	26.9	27.1	27.5	27.8	28.2	28.7	29.2	29.7		0.1	0.2	0.3
10 08.3	24.2	24.4	24.6	24.8	25.1	25.3	25.7	26.0	26.5	26.9	27.4		0.1	0.2	0.2
18.3	22.2	22.3	22.5	22.7	22.9	23.2	23.5	23.8	24.2	24.6	25.1		0.1	0.1	0.2
28.3	20.1	20.2	20.4	20.6	20.8	21.0	21.3	21.6	21.9	22.3	22.7		0.1	0.1	0.2
10 38.3	18.0	18.1	18.2	18.4	18.6	18.8	19.0	19.3	19.6	19.9	20.3		0.1	0.1	0.2
48.2	15.8	15.9	16.0	16.1	16.3	16.5	16.7	17.0	17.2	17.5	17.9		0.1	0.1	0.2
58.2	13.6	13.7	13.8	13.9	14.0	14.2	14.4	14.6	14.8	15.1	15.4		0.0	0.1	0.1
11 08.2	11.4	11.4	11.5	11.6	11.7	11.9	12.0	12.2	12.4	12.6	12.8		0.0	0.1	0.1
18.1	9.1	9.2	9.2	9.3	9.4	9.5	9.7	9.8	9.9	10.1	10.3		0.0	0.1	0.1
28.1	6.9	6.9	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7		0.0	0.0	0.1
11 38.1	4.6	4.6	4.6	4.7	4.7	4.8	4.8	4.9	5.0	5.1	5.2		0.0	0.0	0.0
48.1	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	2.5	2.6		0.0	0.0	0.0
58.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0

See footnote pages 18 and 19 for equation to be employed when values in seconds are required.

Mean Time Hour Angle	AZIMUTH OF POLARIS AT ALL HOUR ANGLES, 1971 — Mean Declination + 89° 08′ 10″ — Latitude											CORR. TO AZIMUTH — Add for Decl. + 89°		
												8′00″	7′50″	7′40″
												Subtract for Decl. + 89°		
	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	8′20″	8′30″	8′40″
h m	′	′	′	′	′	′	′	′	′	′	′	′	′	′
0 00.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0 10.0	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.6	0.0	0.0	0.0
19.9	5.3	5.4	5.5	5.6	5.8	6.0	6.2	6.4	6.6	6.9	7.2	0.0	0.0	0.1
29.9	7.9	8.1	8.2	8.5	8.7	8.9	9.2	9.5	9.9	10.3	10.7	0.0	0.1	0.1
0 39.9	10.5	10.7	11.0	11.2	11.6	11.9	12.3	12.7	13.2	13.7	14.3	0.0	0.1	0.1
49.9	13.1	13.4	13.7	14.0	14.4	14.8	15.3	15.8	16.4	17.0	17.8	0.0	0.1	0.1
59.8	15.6	16.0	16.3	16.8	17.2	17.7	18.3	18.9	19.6	20.4	21.2	0.1	0.1	0.2
1 09.8	18.1	18.5	19.0	19.5	20.0	20.6	21.3	22.0	22.8	23.7	24.7	0.1	0.1	0.2
19.8	20.6	21.1	21.6	22.1	22.8	23.4	24.2	25.0	25.9	26.9	28.1	0.1	0.2	0.2
29.8	23.1	23.6	24.2	24.8	25.5	26.2	27.0	28.0	29.0	30.1	31.4	0.1	0.2	0.3
1 39.7	25.5	26.1	26.7	27.3	28.1	28.9	29.8	30.9	32.0	33.2	34.6	0.1	0.2	0.3
49.7	27.9	28.5	29.1	29.9	30.7	31.6	32.6	33.7	34.9	36.3	37.8	0.1	0.2	0.3
59.7	30.2	30.8	31.5	32.3	33.2	34.2	35.3	36.5	37.8	39.3	41.0	0.1	0.2	0.3
2 09.6	32.4	33.1	33.9	34.7	35.7	36.7	37.9	39.2	40.6	42.2	44.0	0.1	0.2	0.4
19.6	34.6	35.3	36.2	37.1	38.1	39.2	40.5	41.8	43.4	45.1	46.9	0.1	0.3	0.4
29.6	36.7	37.5	38.4	39.3	40.4	41.6	42.9	44.4	46.0	47.8	49.8	0.1	0.3	0.4
2 39.6	38.7	39.6	40.5	41.5	42.7	43.9	45.3	46.8	48.5	50.4	52.6	0.1	0.3	0.4
49.5	40.7	41.6	42.6	43.6	44.8	46.1	47.6	49.2	51.0	53.0	55.2	0.1	0.3	0.4
59.5	42.6	43.5	44.5	45.7	46.9	48.3	49.8	51.5	53.4	55.4	57.8	0.2	0.3	0.5
3 09.5	44.4	45.4	46.4	47.6	48.9	50.3	51.9	53.7	55.6	57.8	60.2	0.2	0.3	0.5
19.5	46.1	47.1	48.2	49.4	50.8	52.3	53.9	55.7	57.7	60.0	62.5	0.2	0.3	0.5
29.4	47.7	48.8	49.9	51.2	52.6	54.1	55.8	57.7	59.8	62.1	64.7	0.2	0.3	0.5
3 39.4	49.3	50.3	51.5	52.8	54.2	55.8	57.6	59.5	61.7	64.1	66.7	0.2	0.4	0.5
49.4	50.7	51.8	53.0	54.4	55.8	57.5	59.3	61.2	63.5	65.9	68.7	0.2	0.4	0.6
59.3	52.1	53.2	54.4	55.8	57.3	59.0	60.8	62.9	65.1	67.6	70.5	0.2	0.4	0.6
4 09.3	53.3	54.5	55.7	57.1	58.7	60.4	62.3	64.3	66.7	69.2	72.1	0.2	0.4	0.6
19.3	54.4	55.6	56.9	58.3	59.9	61.7	63.6	65.7	68.1	70.7	73.6	0.2	0.4	0.6
29.3	55.5	56.7	58.0	59.4	61.0	62.8	64.8	66.9	69.3	72.0	75.0	0.2	0.4	0.6
4 39.2	56.4	57.6	59.0	60.4	62.1	63.9	65.8	68.0	70.5	73.2	76.2	0.2	0.4	0.6
49.2	57.2	58.5	59.8	61.3	63.0	64.8	66.8	69.0	71.5	74.2	77.3	0.2	0.4	0.6
59.2	57.9	59.2	60.5	62.1	63.7	65.6	67.6	69.9	72.4	75.1	78.2	0.2	0.4	0.6
5 09.2	58.5	59.8	61.2	62.7	64.4	66.2	68.3	70.6	73.1	75.9	79.0	0.2	0.4	0.6
19.1	59.0	60.3	61.7	63.2	64.9	66.8	68.8	71.1	73.7	76.5	79.7	0.2	0.4	0.6
29.1	59.4	60.7	62.1	63.6	65.3	67.2	69.3	71.6	74.1	77.0	80.1	0.2	0.4	0.6
5 39.1	59.7	60.9	62.3	63.9	65.6	67.5	69.6	71.9	74.4	77.3	80.4	0.2	0.4	0.7
49.0	59.8	61.1	62.5	64.0	65.7	67.6	69.7	72.0	74.6	77.4	80.6	0.2	0.4	0.7
54.9	...	...	...	...	...	...	...	...	...	...	80.6	0.3	0.5	0.8
5 55.2	...	...	...	...	...	...	...	...	...	77.5	...	0.2	0.5	0.7
55.4	...	...	...	...	...	...	...	...	74.6	...	...	0.2	0.5	0.7
55.7	...	...	...	...	...	...	...	72.1	...	...	...	0.2	0.5	0.7
5 55.9	...	...	...	...	...	...	69.8	...	...	...	...	0.2	0.4	0.7
56.1	...	...	...	...	...	67.7	...	...	...	...	...	0.2	0.4	0.7
56.3	...	...	...	...	65.8	...	...	...	...	...	...	0.2	0.4	0.6
5 56.5	...	...	...	64.1	...	...	...	...	...	...	...	0.2	0.4	0.6
56.7	...	...	62.5	...	...	...	...	...	...	...	...	0.2	0.4	0.6
56.9	...	61.1	...	...	...	...	...	...	...	...	...	0.2	0.4	0.6
5 57.0	59.9	...	...	...	...	...	...	...	...	...	...	0.2	0.4	0.6

Note. The equation shown on the opposite page may be employed when values in seconds are required, also for stations beyond the limits of the latitude tabulations, where:

A = Azimuth angle

t = Sidereal hour angle

φ = Latitude of station

δ = Declination of polaris

Mean Time Hour Angle	AZIMUTH OF POLARIS AT ALL HOUR ANGLES, 1971												CORR. TO AZIMUTH		
	Mean Declination + 89° 08′ 10″												Add for Decl. + 89°		
													8′00″	7′50″	7′40″
	Latitude												Subtract for Decl. + 89°		
	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°		8′20″	8′30″	8′40″
h m	′	′	′	′	′	′	′	′	′	′	′		′	′	′
5 54.9	...	...	...	...	...	...	...	...	...	...	80.6		0.3	0.5	0.8
55.2	...	...	...	...	...	...	...	...	...	77.5	...		0.2	0.5	0.7
55.4	...	...	...	...	...	...	...	...	74.6	...	...		0.2	0.5	0.7
5 55.7	...	...	...	...	...	...	...	72.1	...	...	...		0.2	0.5	0.7
55.9	...	...	...	...	...	...	69.8	...	...	...	...		0.2	0.4	0.7
56.1	...	...	...	...	...	67.7	...	...	...	...	...		0.2	0.4	0.7
5 56.3	...	...	...	...	65.8	...	...	...	...	...	...		0.2	0.4	0.6
56.5	...	...	...	64.1	...	...	...	...	...	...	...		0.2	0.4	0.6
56.7	...	...	62.5	...	...	...	...	...	...	...	...		0.2	0.4	0.6
5 56.9	...	61.1	...	...	...	...	...	...	...	...	...		0.2	0.4	0.6
57.0	59.9	...	...	...	...	...	...	...	...	...	...		0.2	0.4	0.6
59.0	59.9	61.1	62.5	64.1	65.8	67.7	69.7	72.1	74.6	77.5	80.6		0.2	0.4	0.7
6 09.0	59.8	61.0	62.4	64.0	65.7	67.6	69.6	71.9	74.5	77.3	80.5		0.2	0.4	0.7
19.0	59.6	60.8	62.2	63.8	65.5	67.3	69.4	71.7	74.2	77.0	80.2		0.2	0.4	0.6
28.9	59.3	60.5	61.9	63.4	65.1	67.0	69.0	71.3	73.8	76.6	79.8		0.2	0.4	0.6
6 38.9	58.9	60.1	61.5	63.0	64.6	66.5	68.5	70.8	73.3	76.1	79.2		0.2	0.4	0.6
48.9	58.3	59.5	60.9	62.4	64.1	65.9	67.9	70.1	72.6	75.3	78.4		0.2	0.4	0.6
58.9	57.7	58.9	60.2	61.7	63.3	65.1	67.1	69.3	71.8	74.5	77.5		0.2	0.4	0.6
7 08.8	56.9	58.1	59.4	60.9	62.5	64.3	66.2	68.4	70.8	73.5	76.5		0.2	0.4	0.6
18.8	56.1	57.2	58.5	60.0	61.6	63.3	65.2	67.4	69.7	72.4	75.3		0.2	0.4	0.6
28.8	55.1	56.3	57.5	58.9	60.5	62.2	64.1	66.2	68.5	71.1	74.0		0.2	0.4	0.6
7 38.7	54.0	55.2	56.4	57.8	59.3	61.0	62.9	64.9	67.2	69.7	72.5		0.2	0.4	0.6
48.7	52.9	54.0	55.2	56.5	58.0	59.7	61.5	63.5	65.7	68.2	70.9		0.2	0.4	0.6
58.7	51.6	52.7	53.9	55.2	56.6	58.2	60.0	61.9	64.1	66.5	69.2		0.2	0.4	0.6
8 08.7	50.2	51.3	52.4	53.7	55.1	56.7	58.4	60.3	62.4	64.7	67.4		0.2	0.4	0.5
18.6	48.8	49.8	50.9	52.2	53.5	55.0	56.7	58.5	60.6	62.8	65.4		0.2	0.4	0.5
28.6	47.2	48.2	49.3	50.5	51.8	53.3	54.9	56.7	58.6	60.8	63.3		0.2	0.3	0.5
8 38.6	45.6	46.5	47.6	48.7	50.0	51.4	53.0	54.7	56.6	58.7	61.1		0.2	0.3	0.5
48.6	43.9	44.8	45.8	46.9	48.1	49.5	51.0	52.6	54.4	56.5	58.7		0.2	0.3	0.5
58.5	42.1	42.9	43.9	45.0	46.1	47.4	48.9	50.4	52.2	54.1	56.3		0.2	0.3	0.5
9 08.5	40.2	41.0	41.9	42.9	44.1	45.3	46.7	48.2	49.8	51.7	53.8		0.1	0.3	0.4
18.5	38.2	39.0	39.9	40.8	41.9	43.1	44.4	45.8	47.4	49.2	51.1		0.1	0.3	0.4
28.4	36.2	36.9	37.8	38.7	39.7	40.8	42.0	43.4	44.9	46.5	48.4		0.1	0.3	0.4
9 38.4	34.1	34.8	35.6	36.4	37.4	38.4	39.6	40.8	42.3	43.8	45.6		0.1	0.2	0.4
48.4	31.9	32.6	33.3	34.1	35.0	36.0	37.1	38.2	39.6	41.0	42.7		0.1	0.2	0.3
58.4	29.7	30.3	31.0	31.7	32.6	33.5	34.5	35.6	36.8	38.2	39.7		0.1	0.2	0.3
10 08.3	27.4	28.0	28.6	29.3	30.1	30.9	31.8	32.8	34.0	35.2	36.7		0.1	0.2	0.3
18.3	25.1	25.6	26.2	26.8	27.5	28.3	29.1	30.1	31.1	32.2	33.5		0.1	0.2	0.3
28.3	22.7	23.2	23.7	24.3	24.9	25.6	26.4	27.2	28.2	29.2	30.4		0.1	0.2	0.2
10 38.3	20.3	20.7	21.2	21.7	22.3	22.9	23.6	24.3	25.2	26.1	27.1		0.1	0.1	0.2
48.2	17.9	18.2	18.6	19.1	19.6	20.1	20.7	21.4	22.1	22.9	23.8		0.1	0.1	0.2
58.2	15.4	15.7	16.0	16.4	16.8	17.3	17.8	18.4	19.0	19.7	20.5		0.1	0.1	0.2
11 08.2	12.8	13.1	13.4	13.7	14.1	14.5	14.9	15.4	15.9	16.5	17.2		0.0	0.1	0.1
18.1	10.3	10.5	10.7	11.0	11.3	11.6	12.0	12.3	12.8	13.2	13.8		0.0	0.1	0.1
28.1	7.7	7.9	8.1	8.3	8.5	8.7	9.0	9.3	9.6	9.9	10.3		0.0	0.1	0.1
11 38.1	5.2	5.3	5.4	5.5	5.7	5.8	6.0	6.2	6.4	6.6	6.9		0.0	0.0	0.1
48.1	2.6	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.5		0.0	0.0	0.0
58.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0

$$\text{Tan } A = \frac{\sin t}{\cos \varphi \tan \delta - \sin \varphi \cos t}$$

The product " $\sin \varphi \cos t$ " is subtracted for hour angles 0° to 90° and added for hour angles from 90° to 180°.

Mean Time Hour Angle	AZIMUTH OF POLARIS AT ALL HOUR ANGLES, 1971 — Mean Declination + 89°08′ 10″ — Latitude 50°	52°	54°	56°	58°	60°	61°	62°	63°	64°	65°	Az.	CORR. TO AZIMUTH — Add for Decl. + 89° 8′00″ / Subtract for Decl. + 89° 8′20″	7′50″ / 8′30″	7′40″ / 8′40″
h m	′	′	′	′	′	′	′	′	′	′	′		′	′	′
0 00.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0°	0.0	0.0	0.0
0 10.0	3.6	3.7	3.9	4.1	4.4	4.6	4.8	5.0	5.1	5.3	5.5		0.0	0.0	0.0
19.9	7.2	7.5	7.8	8.3	8.7	9.3	9.6	9.9	10.3	10.6	11.0		0.0	0.1	0.1
29.9	10.7	11.2	11.8	12.4	13.1	13.9	14.3	14.8	15.4	15.9	16.5		0.0	0.1	0.1
0 39.9	14.3	14.9	15.6	16.5	17.4	18.5	19.1	19.7	20.4	21.2	22.0		0.1	0.1	0.2
49.9	17.8	18.6	19.5	20.5	21.7	23.0	23.8	24.6	25.4	26.4	27.4		0.1	0.1	0.2
59.8	21.2	22.2	23.3	24.5	25.9	27.5	28.4	29.4	30.4	31.5	32.8		0.1	0.2	0.2
1 09.8	24.7	25.8	27.1	28.5	30.1	32.0	33.0	34.1	35.3	36.6	38.1		0.1	0.2	0.3
19.8	28.1	29.3	30.8	32.4	34.2	36.3	37.5	38.8	40.2	41.7	43.3		0.1	0.2	0.3
29.8	31.4	32.8	34.4	36.2	38.3	40.7	42.0	43.4	44.9	46.6	48.4		0.1	0.2	0.4
1 39.7	34.6	36.2	38.0	40.0	42.3	44.9	46.3	47.9	49.6	51.4	53.4		0.1	0.3	0.4
49.7	37.8	39.6	41.5	43.7	46.2	49.0	50.6	52.3	54.1	56.1	58.3	0°	0.1	0.3	0.4
59.7	41.0	42.8	44.9	47.3	50.0	53.0	54.7	56.6	58.6	0.7	3.1	1°	0.2	0.3	0.5
2 09.6	44.0	46.0	48.2	50.8	53.6	57.0	58.8	0.8	2.9	5.2	7.7		0.2	0.3	0.5
19.6	46.9	49.1	51.5	54.2	57.2	0.8	2.7	4.8	7.1	9.6	12.3		0.2	0.4	0.6
29.6	49.8	52.0	54.6	57.4	0.7	4.4	6.5	8.8	11.2	13.8	16.6		0.2	0.4	0.6
2 39.6	52.6	54.9	57.6	0.6	4.1	8.0	10.2	12.5	15.1	17.8	20.8		0.2	0.4	0.6
49.5	55.2	57.7	0.5	3.7	7.3	11.4	13.7	16.2	18.8	21.7	24.9		0.2	0.4	0.6
59.5	57.8	0.4	3.3	6.6	10.4	14.7	17.1	19.7	22.4	25.5	28.7		0.2	0.5	0.7
3 09.5	0.2	2.9	5.9	9.4	13.3	17.8	20.3	23.0	25.9	29.0	32.4		0.2	0.5	0.7
19.5	2.5	5.3	8.5	12.0	16.1	20.8	23.3	26.1	29.1	32.4	35.9		0.2	0.5	0.7
29.4	4.7	7.6	10.9	14.5	18.7	23.6	26.2	29.1	32.2	35.6	39.2		0.3	0.5	0.8
3 39.4	6.7	9.7	13.1	16.9	21.2	26.2	29.0	31.9	35.1	38.6	42.3		0.3	0.5	0.8
49.4	8.7	11.7	15.2	19.1	23.6	28.7	31.5	34.5	37.8	41.4	45.2		0.3	0.5	0.8
59.3	10.5	13.6	17.2	21.2	25.7	31.0	33.9	37.0	40.3	44.0	47.9		0.3	0.6	0.8
4 09.3	12.1	15.3	19.0	23.1	27.7	33.1	36.0	39.2	42.7	46.4	50.4		0.3	0.6	0.8
19.3	13.6	16.9	20.6	24.8	29.5	35.0	38.0	41.3	44.8	48.6	52.7		0.3	0.6	0.9
29.3	15.0	18.4	22.1	26.4	31.2	36.7	39.8	43.1	46.7	50.5	54.7		0.3	0.6	0.9
4 39.2	16.2	19.6	23.4	27.8	32.7	38.3	41.4	44.7	48.4	52.3	56.5		0.3	0.6	0.9
49.2	17.3	20.8	24.6	29.0	34.0	39.6	42.8	46.2	49.8	53.8	58.1		0.3	0.6	0.9
59.2	18.2	21.7	25.6	30.0	35.1	40.8	44.0	47.4	51.1	55.1	59.4	1°	0.3	0.6	0.9
5 09.2	19.0	22.5	26.5	30.9	36.0	41.8	45.0	48.4	52.2	56.2	0.5	2°	0.3	0.6	0.9
19.1	19.7	23.2	27.1	31.6	36.7	42.5	45.8	49.2	53.0	57.0	1.4		0.3	0.6	0.9
29.1	20.1	23.7	27.7	32.2	37.3	43.1	46.4	49.8	53.6	57.7	2.1		0.3	0.6	0.9
5 39.1	20.4	24.0	28.0	32.5	37.6	43.5	46.7	50.2	54.0	58.1	2.5		0.3	0.6	0.9
49.0	20.6	24.2	28.2	32.7	37.8	43.7	46.9	50.4	54.2	58.3	2.7		0.3	0.6	0.9
51.6	...	...	...	...	...	...	...	...	...	...	2.7		0.4	0.8	1.2
5 51.9	...	...	...	...	...	...	...	...	...	58.3	...		0.4	0.8	1.1
52.3	...	...	...	...	...	...	...	...	54.2	...	...		0.4	0.7	1.1
52.5	...	...	...	...	...	...	...	50.4	...	...	...		0.4	0.7	1.1
5 52.8	...	...	...	...	...	...	46.9	...	...	...	...		0.3	0.7	1.0
53.0	...	...	...	...	...	43.7	...	...	...	...	...		0.3	0.7	1.0
53.5	...	...	...	...	37.8	...	...	...	...	...	...		0.3	0.6	0.9
5 53.9	...	...	...	32.7	...	...	...	...	...	...	...		0.3	0.6	0.9
54.3	...	...	28.2	...	...	...	...	...	...	...	...		0.3	0.6	0.9
54.6	...	24.2	...	...	...	...	...	...	...	...	...		0.3	0.5	0.8
5 54.9	20.6	...	...	...	...	...	...	...	...	...	...	2°	0.3	0.5	0.8

See footnote pages 18 and 19 for equation to be employed when values in seconds are required.

Mean Time Hour Angle	AZIMUTH OF POLARIS AT ALL HOUR ANGLES, 1971												CORR. TO AZIMUTH		
	Mean Declination + 89° 08′ 10″												Add for Decl. + 89°		
													8′00″	7′50″	7′40″
	Latitude												Subtract for Decl. + 89°		
	50°	52°	54°	56°	58°	60°	61°	62°	63°	64°	65°	Az.	8′20″	8′30″	8′40″
h m	′	′	′	′	′	′	′	′	′	′	′		′	′	′
5 51.6	...	...	...	...	...	...	...	...	...	...	2.7	2°	0.4	0.8	1.2
51.9	...	...	...	...	...	...	...	...	...	58.3	...		0.4	0.8	1.1
52.3	...	...	...	...	...	...	...	...	54.2	...	...		0.4	0.7	1.1
5 52.5	...	...	...	...	...	...	...	50.4	...	...	...		0.4	0.7	1.1
52.8	...	...	...	...	...	...	46.9	...	...	...	...		0.3	0.7	1.0
53.0	...	...	...	...	...	43.7	...	...	...	...	...		0.3	0.7	1.0
5 53.5	...	...	...	...	37.8	...	...	...	...	...	...		0.3	0.6	0.9
53.9	...	...	...	32.7	...	...	...	...	...	...	...		0.3	0.6	0.9
54.3	...	...	28.2	...	...	...	...	...	...	...	...		0.3	0.6	0.9
5 54.6	...	24.2	...	...	...	...	...	...	...	...	...		0.3	0.5	0.8
54.9	20.6	...	...	...	...	...	...	...	...	...	...		0.3	0.5	0.8
59.0	20.6	24.2	28.2	32.7	37.8	43.6	46.9	50.4	54.1	58.2	2.6		0.3	0.6	0.9
6 09.0	20.5	24.0	28.0	32.5	37.6	43.4	46.7	50.1	53.9	57.9	2.3		0.3	0.6	0.9
19.0	20.2	23.7	27.7	32.1	37.2	43.0	46.2	49.7	53.4	57.4	1.8		0.3	0.6	0.9
28.9	19.8	23.3	27.2	31.6	36.7	42.4	45.6	49.0	52.7	56.7	1.0		0.3	0.6	0.9
6 38.9	19.2	22.6	26.5	30.9	35.9	41.6	44.8	48.2	51.8	55.8	0.1	2°	0.3	0.6	0.9
48.9	18.4	21.8	25.7	30.0	35.0	40.6	43.7	47.1	50.7	54.6	58.9	1°	0.3	0.6	0.9
58.9	17.5	20.9	24.7	29.0	33.9	39.4	42.5	45.8	49.4	53.3	57.4		0.3	0.6	0.9
7 08.8	16.5	19.8	23.6	27.8	32.6	38.1	41.1	44.4	47.9	51.7	55.8		0.3	0.6	0.9
18.8	15.3	18.6	22.3	26.4	31.1	36.5	39.5	42.7	46.2	49.9	54.0		0.3	0.6	0.9
28.8	14.0	17.2	20.8	24.9	29.5	34.8	37.7	40.9	44.3	47.9	51.9		0.3	0.6	0.9
7 38.7	12.5	15.7	19.2	23.2	27.7	32.9	35.8	38.9	42.2	45.8	49.6		0.3	0.6	0.8
48.7	10.9	14.0	17.5	21.4	25.8	30.8	33.6	36.6	39.9	43.4	47.2		0.3	0.6	0.8
58.7	9.2	12.2	15.6	19.4	23.7	28.6	31.3	34.3	37.4	40.8	44.5		0.3	0.5	0.8
8 08.7	7.4	10.3	13.5	17.2	21.4	26.2	28.9	31.7	34.8	38.1	41.7		0.3	0.5	0.8
18.6	5.4	8.2	11.4	15.0	19.0	23.7	26.2	29.0	31.9	35.2	38.6		0.3	0.5	0.8
28.6	3.3	6.0	9.1	12.5	16.5	20.9	23.4	26.1	29.0	32.1	35.4		0.2	0.5	0.7
8 38.6	1.1	3.7	6.7	10.0	13.8	18.1	20.5	23.1	25.8	28.8	32.0		0.2	0.5	0.7
48.6	58.7	1.3	4.1	7.3	11.0	15.1	17.4	19.9	22.5	25.4	28.5		0.2	0.5	0.7
58.5	56.3	58.7	1.5	4.5	8.0	12.0	14.2	16.5	19.1	21.8	24.8		0.2	0.4	0.7
9 08.5	53.8	56.1	58.7	1.6	4.9	8.7	10.8	13.1	15.5	18.1	20.9		0.2	0.4	0.6
18.5	51.1	53.3	55.8	58.6	1.7	5.3	7.3	9.5	11.8	14.2	16.9		0.2	0.4	0.6
28.4	48.4	50.5	52.8	55.4	58.4	1.8	3.7	5.7	7.9	10.3	12.8		0.2	0.4	0.6
9 38.4	45.6	47.5	49.7	52.2	55.0	58.2	0.0	1.9	3.9	6.1	8.5		0.2	0.4	0.5
48.4	42.7	44.5	46.6	48.9	51.5	54.5	56.2	57.9	59.8	1.9	4.1	1°	0.2	0.3	0.5
58.4	39.7	41.4	43.3	45.5	47.9	50.7	52.2	53.9	55.7	57.6	59.7	0°	0.2	0.3	0.5
10 08.3	36.7	38.2	40.0	42.0	44.2	46.8	48.2	49.7	51.4	53.1	55.1		0.1	0.3	0.4
18.3	33.5	35.0	36.6	38.4	40.5	42.8	44.1	45.5	47.0	48.6	50.4		0.1	0.3	0.4
28.3	30.4	31.7	33.1	34.8	36.6	38.7	39.9	41.2	42.5	44.0	45.6		0.1	0.2	0.4
10 38.3	27.1	28.3	29.6	31.1	32.7	34.6	35.7	36.8	38.0	39.3	40.7		0.1	0.2	0.3
48.2	23.8	24.9	26.0	27.3	28.8	30.4	31.3	32.3	33.4	34.5	35.8		0.1	0.2	0.3
58.2	20.5	21.4	22.4	23.5	24.7	26.2	27.0	27.8	28.7	29.7	30.8		0.1	0.2	0.2
11 08.2	17.2	17.9	18.7	19.6	20.7	21.9	22.5	23.3	24.0	24.8	25.7		0.1	0.1	0.2
18.1	13.8	14.3	15.0	15.8	16.6	17.6	18.1	18.7	19.3	19.9	20.6		0.1	0.1	0.2
28.1	10.3	10.8	11.3	11.8	12.5	13.2	13.6	14.0	14.5	15.0	15.5		0.0	0.1	0.1
11 38.1	6.9	7.2	7.5	7.9	8.3	8.8	9.1	9.4	9.7	10.0	10.4		0.0	0.1	0.1
48.1	3.5	3.6	3.8	4.0	4.2	4.4	4.5	4.7	4.8	5.0	5.2		0.0	0.0	0.0
58.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0°	0.0	0.0	0.0

See footnote pages 18 and 19 for equation to be employed when values in seconds are required.

Lat.	Correction to the Time of Elongation	AZIMUTH OF POLARIS AT ELONGATION, 1971						
		Decl. + 89°						
		7′ 40″	7′ 50″	8′ 00″	8′ 10″	8′ 20″	8′ 30″	8′ 40″
° ′	W.E. m E.E.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
10 00	+2.3−	0 53 08	0 52 58	0 52 48	0 52 38	0 52 28	0 52 18	0 52 08
12 00	2.2	0 53 30	0 53 20	0 53 10	0 52 59	0 52 49	0 52 39	0 52 29
14 00	2.0	0 53 56	0 53 46	0 53 36	0 53 25	0 53 15	0 53 05	0 52 54
16 00	1.9	0 54 27	0 54 16	0 54 06	0 53 55	0 53 45	0 53 35	0 53 24
18 00	1.8	0 55 02	0 54 51	0 54 41	0 54 30	0 54 20	0 54 09	0 53 59
20 00	1.6	0 55 42	0 55 31	0 55 20	0 55 10	0 54 59	0 54 48	0 54 38
21 00	1.6	0 56 03	0 55 53	0 55 42	0 55 31	0 55 21	0 55 10	0 54 59
22 00	1.5	0 56 27	0 56 16	0 56 05	0 55 54	0 55 43	0 55 33	0 55 22
23 00	1.4	0 56 51	0 56 40	0 56 29	0 56 19	0 56 08	0 55 57	0 55 46
24 00	1.4	0 57 17	0 57 06	0 56 55	0 56 44	0 56 33	0 56 22	0 56 12
25 00	1.3	0 57 45	0 57 34	0 57 23	0 57 12	0 57 00	0 56 49	0 56 38
26 00	1.2	0 58 14	0 58 02	0 57 51	0 57 40	0 57 29	0 57 18	0 57 07
27 00	1.1	0 58 44	0 58 33	0 58 22	0 58 10	0 57 59	0 57 48	0 57 37
28 00	1.1	0 59 16	0 59 05	0 58 54	0 58 42	0 58 31	0 58 20	0 58 08
29 00	1.0	0 59 50	0 59 39	0 59 27	0 59 16	0 59 04	0 58 53	0 58 42
30 00	0.9	1 00 26	1 00 14	1 00 03	0 59 51	0 59 40	0 59 28	0 59 17
31 00	0.8	1 01 03	1 00 52	1 00 40	1 00 28	1 00 17	1 00 05	0 59 53
32 00	0.7	1 01 43	1 01 31	1 01 19	1 01 07	1 00 56	1 00 44	1 00 32
33 00	0.7	1 02 24	1 02 12	1 02 00	1 01 48	1 01 36	1 01 24	1 01 13
34 00	0.6	1 03 08	1 02 56	1 02 43	1 02 31	1 02 19	1 02 07	1 01 55
35 00	0.5	1 03 53	1 03 41	1 03 29	1 03 17	1 03 04	1 02 52	1 02 40
36 00	0.4	1 04 41	1 04 29	1 04 17	1 04 04	1 03 52	1 03 40	1 03 27
37 00	0.3	1 05 32	1 05 19	1 05 07	1 04 54	1 04 42	1 04 29	1 04 17
38 00	0.2	1 06 25	1 06 12	1 05 59	1 05 47	1 05 34	1 05 21	1 05 09
39 00	+0.1−	1 07 21	1 07 08	1 06 55	1 06 42	1 06 29	1 06 16	1 06 03
40 00	0.0	1 08 19	1 08 06	1 07 53	1 07 40	1 07 27	1 07 14	1 07 01
41 00	−0.1+	1 09 21	1 09 07	1 08 54	1 08 41	1 08 28	1 08 14	1 08 01
42 00	0.2	1 10 25	1 10 12	1 09 59	1 09 45	1 09 32	1 09 18	1 09 05
43 00	0.3	1 11 34	1 11 20	1 11 06	1 10 53	1 10 39	1 10 25	1 10 12
44 00	0.4	1 12 45	1 12 31	1 12 17	1 12 04	1 11 50	1 11 36	1 11 22
45 00	0.6	1 14 01	1 13 47	1 13 33	1 13 18	1 13 04	1 12 50	1 12 36
46 00	0.7	1 15 20	1 15 06	1 14 52	1 14 37	1 14 23	1 14 08	1 13 54
47 00	0.8	1 16 44	1 16 30	1 16 15	1 16 00	1 15 46	1 15 31	1 15 16
48 00	0.9	1 18 13	1 17 58	1 17 43	1 17 28	1 17 13	1 16 58	1 16 43
49 00	1.1	1 19 46	1 19 31	1 19 16	1 19 01	1 18 45	1 18 30	1 18 15
50 00	1.2	1 21 25	1 21 10	1 20 54	1 20 39	1 20 23	1 20 07	1 19 52
51 00	1.4	1 23 10	1 22 54	1 22 38	1 22 22	1 22 06	1 21 50	1 21 34
52 00	1.5	1 25 01	1 24 44	1 24 28	1 24 12	1 23 56	1 23 39	1 23 23
53 00	1.7	1 26 58	1 26 41	1 26 25	1 26 08	1 25 51	1 25 35	1 25 18
54 00	1.9	1 29 02	1 28 45	1 28 28	1 28 11	1 27 54	1 27 37	1 27 20
55 00	2.0	1 31 15	1 30 57	1 30 40	1 30 23	1 30 05	1 29 48	1 29 30
55 30	2.1	1 32 24	1 32 07	1 31 49	1 31 31	1 31 14	1 30 56	1 30 38
56 00	2.2	1 33 36	1 33 18	1 33 00	1 32 42	1 32 24	1 32 06	1 31 48
56 30	2.3	1 34 50	1 34 31	1 34 13	1 33 55	1 33 37	1 33 19	1 33 01
57 00	2.4	1 36 06	1 35 47	1 35 29	1 35 11	1 34 52	1 34 34	1 34 16
57 30	2.5	1 37 25	1 37 06	1 36 47	1 36 29	1 36 10	1 35 52	1 35 33
58 00	2.6	1 38 46	1 38 27	1 38 08	1 37 49	1 37 31	1 37 12	1 36 53
58 30	2.7	1 40 10	1 39 51	1 39 32	1 39 13	1 38 54	1 38 34	1 38 15
59 00	2.9	1 41 37	1 41 18	1 40 58	1 40 39	1 40 20	1 40 00	1 39 41
59 30	3.0	1 43 07	1 42 48	1 42 28	1 42 08	1 41 49	1 41 29	1 41 09
60 00	3.1	1 44 41	1 44 21	1 44 01	1 43 41	1 43 21	1 43 01	1 42 41
60 30	3.2	1 46 17	1 45 57	1 45 37	1 45 16	1 44 56	1 44 36	1 44 16
61 00	3.3	1 47 58	1 47 37	1 47 16	1 46 56	1 46 35	1 46 14	1 45 54
61 30	3.5	1 49 41	1 49 21	1 49 00	1 48 39	1 48 18	1 47 57	1 47 36
62 00	3.6	1 51 29	1 51 08	1 50 47	1 50 25	1 50 04	1 49 43	1 49 21
62 30	3.7	1 53 21	1 53 00	1 52 38	1 52 16	1 51 55	1 51 33	1 51 11
63 00	3.9	1 55 17	1 54 55	1 54 33	1 54 11	1 53 49	1 53 27	1 53 05
63 30	4.0	1 57 18	1 56 56	1 56 33	1 56 11	1 55 49	1 55 26	1 55 04
64 00	4.2	1 59 24	1 59 01	1 58 38	1 58 16	1 57 53	1 57 30	1 57 07
64 30	4.3	2 01 35	2 01 12	2 00 48	2 00 25	2 00 02	1 59 39	1 59 15
65 00	4.5	2 03 51	2 03 28	2 03 04	2 02 40	2 02 16	2 01 53	2 01 29
65 30	4.7	2 06 13	2 05 49	2 05 25	2 05 01	2 04 37	2 04 13	2 03 49
66 00	4.9	2 08 41	2 08 17	2 07 52	2 07 28	2 07 03	2 06 38	2 06 14
66 30	5.0	2 11 16	2 10 51	2 10 26	2 10 01	2 09 36	2 09 11	2 08 46
67 00	5.2	2 13 58	2 13 32	2 13 07	2 12 41	2 12 16	2 11 50	2 11 24
67 30	5.4	2 16 47	2 16 21	2 15 55	2 15 29	2 15 02	2 14 36	2 14 10
68 00	5.7	2 19 44	2 19 17	2 18 51	2 18 24	2 17 57	2 17 31	2 17 04
68 30	5.9	2 22 50	2 22 22	2 21 55	2 21 28	2 21 00	2 20 33	2 20 06
69 00	6.1	2 26 04	2 25 36	2 25 08	2 24 40	2 24 13	2 23 45	2 23 17
69 30	6.3	2 29 29	2 29 00	2 28 31	2 28 03	2 27 34	2 27 06	2 26 37
70 00	−6.6+	2 33 03	2 32 34	2 32 05	2 31 36	2 31 06	2 30 37	2 30 08

TO FIND THE LATITUDE BY AN ALTITUDE OBSERVATION OF POLARIS AT ANY HOUR ANGLE, 1971

Mean Time Hour Angle	Primary Adjustment to Elevation of Pole — Subtract — Polaris Above the Pole — Decl. + 89°				Add — Polaris Below the Pole — Decl. + 89°				Mean Time Hour Angle
	7′ 40″	8′ 00″	8′ 20″	8′ 40″	7′ 40″	8′ 00″	8′ 20″	8′ 40″	
h m	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	h m
0 00.0	0 52 20	0 52 00	0 51 40	0 51 20	0 00 00	0 00 00	0 00 00	0 00 00	5 57.3
					0 00 24	0 00 24	0 00 23	0 00 23	5 59.0
0 12.0	0 52 16	0 51 56	0 51 36	0 51 16	0 01 46	0 01 45	0 01 44	0 01 44	6 05.0
23.9	52 03	51 43	51 23	51 03	03 08	03 07	03 05	03 04	11.0
35.9	51 41	51 21	51 01	50 42	04 30	04 28	04 26	04 25	17.0
47.9	51 10	50 51	50 31	50 12	05 52	05 49	05 47	05 45	23.0
59.8	50 31	50 12	49 53	49 34	07 13	07 10	07 08	07 05	28.9
1 11.8	0 49 44	0 49 25	0 49 06	0 48 47	0 08 35	0 08 31	0 08 28	0 08 24	6 34.9
23.8	48 48	48 30	48 11	47 53	09 55	09 51	09 47	09 44	40.9
35.7	47 45	47 26	47 08	46 50	11 16	11 11	11 07	11 02	46.9
47.7	46 33	46 15	45 57	45 40	12 36	12 31	12 26	12 21	52.9
59.7	45 13	44 56	44 39	44 22	13 55	13 50	13 44	13 39	58.9
2 11.6	0 43 46	0 43 30	0 43 13	0 42 56	0 15 14	0 15 08	0 15 02	0 14 56	7 04.8
23.6	42 12	41 56	41 40	41 24	16 32	16 26	16 19	16 13	10.8
35.6	40 31	40 15	40 00	39 45	17 49	17 43	17 36	17 29	16.8
47.5	38 43	38 28	38 13	37 59	19 06	18 59	18 51	18 44	22.8
59.5	36 48	36 34	36 20	36 06	20 22	20 14	20 06	19 58	28.8
3 05.5	0 35 49	0 35 35	0 35 22	0 35 08	0 21 37	0 21 29	0 21 20	0 21 12	7 34.8
11.5	34 48	34 35	34 22	34 08	22 51	22 43	22 34	22 25	40.7
17.5	33 46	33 33	33 20	33 07	24 05	23 55	23 46	23 37	46.7
23.4	32 42	32 29	32 17	32 05	25 17	25 07	24 57	24 47	52.7
29.4	31 37	31 25	31 13	31 01	26 28	26 18	26 08	25 57	58.7
3 35.4	0 30 30	0 30 19	0 30 07	0 29 55	0 27 38	0 27 27	0 27 17	0 27 06	8 04.7
41.4	29 22	29 11	29 00	28 49	28 47	28 36	28 25	28 14	10.7
47.4	28 13	28 03	27 52	27 41	29 55	29 43	29 32	29 20	16.6
53.4	27 03	26 53	26 43	26 33	31 01	30 49	30 37	30 26	22.6
59.3	25 52	25 42	25 33	25 23	32 07	31 54	31 42	31 30	28.6
4 05.3	0 24 40	0 24 31	0 24 21	0 24 12	0 33 11	0 32 58	0 32 45	0 32 32	8 34.6
11.3	23 27	23 18	23 09	23 00	34 13	34 00	33 47	33 34	40.6
17.3	22 12	22 04	21 56	21 47	35 14	35 01	34 47	34 34	46.6
23.3	20 57	20 49	20 42	20 34	36 14	36 00	35 46	35 32	52.5
29.3	19 41	19 34	19 27	19 19	37 12	36 58	36 44	36 29	58.5
4 35.2	0 18 25	0 18 18	0 18 11	0 18 04	0 39 04	0 38 49	0 38 34	0 38 19	9 10.5
41.2	17 07	17 01	16 54	16 48	40 50	40 34	40 18	40 03	22.5
47.2	15 49	15 43	15 37	15 31	42 29	42 12	41 56	41 40	34.4
53.2	14 30	14 24	14 19	14 14	44 01	43 44	43 27	43 10	46.4
59.2	13 10	13 06	13 01	12 56	45 25	45 08	44 51	44 33	58.4
5 05.2	0 11 50	0 11 46	0 11 42	0 11 37	0 46 43	0 46 25	0 46 07	0 45 49	10 10.3
11.1	10 30	10 26	10 22	10 18	47 53	47 34	47 16	46 58	22.3
17.1	09 09	09 06	09 02	08 59	48 55	48 36	48 17	47 58	34.3
23.1	07 48	07 45	07 42	07 39	49 49	49 30	49 11	48 51	46.2
29.1	06 26	06 24	06 22	06 19	50 35	50 15	49 56	49 37	58.2
5 35.1	0 05 05	0 05 03	0 05 01	0 04 59	0 51 12	0 50 53	0 50 33	0 50 14	11 10.2
41.1	03 43	03 41	03 40	03 39	51 42	51 22	51 02	50 43	22.1
47.0	02 21	02 20	02 19	02 18	52 03	51 43	51 23	51 03	34.1
53.0	00 58	00 58	00 58	00 58	52 16	51 56	51 36	51 16	46.1
57.3	00 00	00 00	00 00	00 00	52 20	52 00	51 40	51 20	58.0

Mean Time Hour Angle	Supplemental Correction to be Applied to the Vertical Angle Reading — Altitude													Mean Time Hour Angle
	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	
h m	″	″	″	″	″	″	″	″	″	″	″	″	″	h m
0 00	0	0	0	0	0	0	0	0	0	0	0	0	0	11 58
1 00	− 1	− 1	− 1	− 1	− 1	0	0	0	0	+ 1	+ 1	+ 2	+ 3	10 58
2 00	5	4	4	3	2	− 2	− 1	0	+ 1	3	4	7	10	9 58
3 00	10	9	7	6	5	4	2	0	2	5	9	13	20	8 58
3 59	14	13	11	9	7	5	3	0	3	8	13	20	31	7 59
4 59	18	16	14	12	9	7	4	0	4	9	16	25	38	6 59
5 59	−19	−17	−15	−13	−10	− 7	− 4	0	+ 4	+10	+17	+27	+41	5 59

EXPLANATIONS FOR THE STELLAR OBSERVATIONS

The data in this Ephemeris are arranged for the surveying practice of the Bureau of Land Management; the methods are useful in any survey where field observations are to be made for the ascertainment of the direction of a line in terms of angular value referred to the true meridian at that place.

In most cases, data are available as to the approximate latitude and longitude of the observing station, and preliminary determinations are made for the meridian and watch correction in terms of local mean time. The observations of the stars then follow on an observing program arranged for what is needed, and to suit the time of year, the latitude of the station, and other conditions that are factors.

A complete and well balanced stellar observing program will include: (1) the meridian passage of one star for time and latitude; (2) Polaris for azimuth and latitude; and (3) two well placed stars, one easterly and one westerly, both for azimuth, and one or both for time. The necessary verifications are thus accomplished. Instrumental uncertainties in the vertical angle readings are made apparent by this plan, and are compensated by taking the means of offsetting values. An observation may be made to verify only one or two values when the remainder are already well determined.

There are six stellar observing periods: (1) late afternoon, daylight; (2) early evening, twilight; (3) later p. m., after dark, illumination required; (4) after midnight, ditto; (5) early morning, twilight; and (6) after sunrise, daylight. The stars to be observed are chosen after deciding upon the observing period, and making the selection according to the desired position in hour angle and declination.

The time of a star's transit is to be reduced from the tabulated value for the Greenwich meridian to the longitude of the station; this is 10 seconds of time for each 15° (or one hour) of longitude, subtracted for west longitude (see table of Sidereal Conversions, page 27); this will give the correct local mean time at the moment of the star's meridian passage. The next step is to anticipate the probable local mean time of each observation, and the star's hour angle at that moment, to the east or to the west of the meridian.

The setting positions for the instrument in vertical angle (v) and in horizontal angle (A) are computed on the basis of the assumed hour angle (t), the star's declination (δ), and the known or approximate latitude (φ). This is done to secure a setting that is sufficiently accurate to bring the star within the field of the telescope, especially if the observation is to be by daylight, or twilight; less accuracy is needed just for the star's identification if the observation is to be made during starlight. The preliminary computations may be made with 4-place tables. The true values are obtained by reduction of the observations. The reductions for stellar observations are similar to the methods applicable to observations of the sun, and employ the same equations.

In all stellar observations, the true vertical angle (h) is equal to the observed vertical angle (v) minus the refraction (r) in zenith distance; there is no correction for parallax. In observations of the sun, the true vertical angle (h) is equal to (v) minus (r) plus parallax; see table, page 25.

In observations of the sun, the meridian passage and the hour angle (t) are in apparent solar time. The equation of time is applied to give the watch correction in terms of local mean time.

In observations of a star, the hour angle (t) is in terms of a sidereal rate; a subtraction of 10 seconds per hour will give the equivalent mean time hour angle. (Sidereal Conversions, page 27).

The following equations are regarded as the most useful for the methods stated above:

On the meridian, the vertical angle: $h = 90° - \varphi \pm \delta$; (or) $\varphi = 90° - h \pm \delta$

$$\text{At any hour angle: } \sin h = \cos t \cos \varphi \cos \delta + \sin \varphi \sin \delta$$

$$: \cos t = \frac{\sin h}{\cos \varphi \cos \delta} - \tan \varphi \tan \delta$$

$$: \cos A = \frac{\sin \delta}{\cos \varphi \cos h} - \tan \varphi \tan h$$

The product "$\sin \varphi \sin \delta$" and the fraction "$\dfrac{\sin \delta}{\cos \varphi \cos h}$" are negative for south declinations.

The product "$\cos t \cos \varphi \cos \delta$" is negative for hour angles exceeding six hours or 90°.

The product "$\tan \varphi \tan \delta$" is subtracted for north declinations; added for south declinations.

If the result for "cos A" is $\begin{Bmatrix}\text{positive}\\\text{negative}\end{Bmatrix}$ the horizontal angle counts from the $\begin{Bmatrix}\text{north.}\\\text{south.}\end{Bmatrix}$

If the result for "cos t" is $\begin{Bmatrix}\text{positive}\\\text{negative}\end{Bmatrix}$ the hour angle is $\begin{Bmatrix}\text{less}\\\text{more}\end{Bmatrix}$ than six hours or 90°.

By a stellar equal-altitude observation, the meridian is determined as the mean of two direction-pointings; the latitude is not required; there are no corrections as to declination. A mean of the watch readings at the moment of each observation is equivalent to a reading at the time of the star's meridian passage. The latitude may be reduced from the maximum vertical angle at meridian passage.

The equations as written and explained above are applicable for the northern latitudes; suitable transpositions are required for observations in the southern latitudes.

MEAN REFRACTIONS IN ZENITH DISTANCE AND SUN'S PARALLAX IN ALTITUDE
Bar. : 29.6 ins. Temp. : 50° F.

Apparent Altitude	Refraction	Sun's Par.	Apparent Altitude	Refraction	Sun's Par.	Apparent Altitude	Refraction	Sun's Par.
° '	' "	"	° '	' "	"	°	' "	"
7 30	6 53	8.8	12 0	4 25	8.7	25	2 3	8.1
7 40	6 45	8.8	12 30	4 15	8.7	26	1 58	8.0
7 50	6 37	8.8	13 0	4 5	8.7	27	1 53	7.9
8 0	6 30	8.8	13 30	3 56	8.7	28	1 48	7.9
8 10	6 22	8.8	14 0	3 47	8.6	29	1 44	7.8
8 20	6 15	8.8	14 30	3 39	8.6	30	1 40	7.7
8 30	6 8	8.8	15 0	3 32	8.6	32	1 32	7.6
8 40	6 2	8.8	15 30	3 25	8.6	34	1 25	7.4
8 50	5 55	8.8	16 0	3 19	8.6	36	1 19	7.2
9 0	5 49	8.8	16 30	3 13	8.5	38	1 14	7.0
9 10	5 43	8.8	17 0	3 7	8.5	40	1 9	6.8
9 20	5 38	8.8	17 30	3 1	8.5	42	1 4	6.6
9 30	5 32	8.8	18 0	2 56	8.5	44	1 0	6.4
9 40	5 26	8.8	18 30	2 51	8.4	46	0 56	6.2
9 50	5 21	8.8	19 0	2 46	8.4	48	0 52	6.0
10 0	5 16	8.8	19 30	2 42	8.4	50	0 48	5.7
10 20	5 6	8.8	20 0	2 37	8.4	55	0 40	5.1
10 40	4 57	8.7	21 0	2 29	8.3	60	0 33	4.4
11 0	4 48	8.7	22 0	2 22	8.2	65	0 27	3.8
11 20	4 40	8.7	23 0	2 15	8.2	70	0 21	3.0
11 40	4 32	8.7	24 0	2 9	8.1	80	0 10	1.5
12 0	4 25	8.7	25 0	2 3	8.1	90	0 0	0.0

Apparent altitude (observed vertical angle) : v
Sun's true altitude : h = v - refraction + parallax
Star's true altitude : h = v - refraction

True refraction : mean refraction x coefficient for barometric pressure x coefficient for temperature.

COEFFICIENTS TO APPLY TO MEAN REFRACTIONS FOR VARIATIONS IN BAROMETER AND TEMPERATURE

Barometer (Ins.)	Elevation above sea level (Feet)	Coefficient	Barometer (Ins.)	Elevation above sea level (Feet)	Coefficient	Barometer (Ins.)	Elevation above sea level (Feet)	Coefficient	Temperature (Fahr.)	Coefficient
30.5	-451	1.03	27.2	2,670	0.92	23.6	6,538	0.80	-10°	1.13
30.2	-181	1.02	26.9	2,972	.91	23.3	6,887	.79	0°	1.11
30.0	00	1.01	26.6	3,277	.90	23.0	7,239	.78	+10°	1.08
29.9	+ 91	1.01	26.3	3,586	.89	22.7	7,597	.77	20°	1.06
29.6	366	1.00	26.0	3,899	.88	22.4	7,960	.76	30°	1.04
29.3	643	.99	25.7	4,215	.87	22.1	8,327	.75	40°	1.02
29.0	924	.98	25.4	4,535	.86	21.8	8,700	.74	50°	1.00
28.7	1,207	.97	25.1	4,859	.85	21.5	9,077	.73	60°	.98
28.4	1,493	.96	24.8	5,186	.84	21.2	9,460	.72	70°	.96
28.1	1,783	.95	24.5	5,518	.83	20.9	9,848	.71	80°	.94
27.8	2,075	.94	24.2	5,854	.82	20.6	10,242	.70	90°	.93
27.5	2,371	.93	23.9	6,194	.81	20.3	10,642	.69	100°	.91
27.2	2,670	.92	23.6	6,538	.80	20.0	11,047	.68	+110°	.90

CONVERSION OF TIME TO ARC

Minutes	Hours												
	0	1	2	3	4	5	6	7	8	9	10	11	12
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 00	15 00	30 00	45 00	60 00	75 00	90 00	105 00	120 00	135 00	150 00	165 00	180 00
1	0 15	15 15	30 15	45 15	60 15	75 15	90 15	105 15	120 15	135 15	150 15	165 15	180 15
2	0 30	15 30	30 30	45 30	60 30	75 30	90 30	105 30	120 30	135 30	150 30	165 30	180 30
3	0 45	15 45	30 45	45 45	60 45	75 45	90 45	105 45	120 45	135 45	150 45	165 45	180 45
4	1 00	16 00	31 00	46 00	61 00	76 00	91 00	106 00	121 00	136 00	151 00	166 00	181 00
5	1 15	16 15	31 15	46 15	61 15	76 15	91 15	106 15	121 15	136 15	151 15	166 15	181 15
6	1 30	16 30	31 30	46 30	61 30	76 30	91 30	106 30	121 30	136 30	151 30	166 30	181 30
7	1 45	16 45	31 45	46 45	61 45	76 45	91 45	106 45	121 45	136 45	151 45	166 45	181 45
8	2 00	17 00	32 00	47 00	62 00	77 00	92 00	107 00	122 00	137 00	152 00	167 00	182 00
9	2 15	17 15	32 15	47 15	62 15	77 15	92 15	107 15	122 15	137 15	152 15	167 15	182 15
10	2 30	17 30	32 30	47 30	62 30	77 30	92 30	107 30	122 30	137 30	152 30	167 30	182 30
11	2 45	17 45	32 45	47 45	62 45	77 45	92 45	107 45	122 45	137 45	152 45	167 45	182 45
12	3 00	18 00	33 00	48 00	63 00	78 00	93 00	108 00	123 00	138 00	153 00	168 00	183 00
13	3 15	18 15	33 15	48 15	63 15	78 15	93 15	108 15	123 15	138 15	153 15	168 15	183 15
14	3 30	18 30	33 30	48 30	63 30	78 30	93 30	108 30	123 30	138 30	153 30	168 30	183 30
15	3 45	18 45	33 45	48 45	63 45	78 45	93 45	108 45	123 45	138 45	153 45	168 45	183 45
16	4 00	19 00	34 00	49 00	64 00	79 00	94 00	109 00	124 00	139 00	154 00	169 00	184 00
17	4 15	19 15	34 15	49 15	64 15	79 15	94 15	109 15	124 15	139 15	154 15	169 15	184 15
18	4 30	19 30	34 30	49 30	64 30	79 30	94 30	109 30	124 30	139 30	154 30	169 30	184 30
19	4 45	19 45	34 45	49 45	64 45	79 45	94 45	109 45	124 45	139 45	154 45	169 45	184 45
20	5 00	20 00	35 00	50 00	65 00	80 00	95 00	110 00	125 00	140 00	155 00	170 00	185 00
21	5 15	20 15	35 15	50 15	65 15	80 15	95 15	110 15	125 15	140 15	155 15	170 15	185 15
22	5 30	20 30	35 30	50 30	65 30	80 30	95 30	110 30	125 30	140 30	155 30	170 30	185 30
23	5 45	20 45	35 45	50 45	65 45	80 45	95 45	110 45	125 45	140 45	155 45	170 45	185 45
24	6 00	21 00	36 00	51 00	66 00	81 00	96 00	111 00	126 00	141 00	156 00	171 00	186 00
25	6 15	21 15	36 15	51 15	66 15	81 15	96 15	111 15	126 15	141 15	156 15	171 15	186 15
26	6 30	21 30	36 30	51 30	66 30	81 30	96 30	111 30	126 30	141 30	156 30	171 30	186 30
27	6 45	21 45	36 45	51 45	66 45	81 45	96 45	111 45	126 45	141 45	156 45	171 45	186 45
28	7 00	22 00	37 00	52 00	67 00	82 00	97 00	112 00	127 00	142 00	157 00	172 00	187 00
29	7 15	22 15	37 15	52 15	67 15	82 15	97 15	112 15	127 15	142 15	157 15	172 15	187 15
30	7 30	22 30	37 30	52 30	67 30	82 30	97 30	112 30	127 30	142 30	157 30	172 30	187 30
31	7 45	22 45	37 45	52 45	67 45	82 45	97 45	112 45	127 45	142 45	157 45	172 45	187 45
32	8 00	23 00	38 00	53 00	68 00	83 00	98 00	113 00	128 00	143 00	158 00	173 00	188 00
33	8 15	23 15	38 15	53 15	68 15	83 15	98 15	113 15	128 15	143 15	158 15	173 15	188 15
34	8 30	23 30	38 30	53 30	68 30	83 30	98 30	113 30	128 30	143 30	158 30	173 30	188 30
35	8 45	23 45	38 45	53 45	68 45	83 45	98 45	113 45	128 45	143 45	158 45	173 45	188 45
36	9 00	24 00	39 00	54 00	69 00	84 00	99 00	114 00	129 00	144 00	159 00	174 00	189 00
37	9 15	24 15	39 15	54 15	69 15	84 15	99 15	114 15	129 15	144 15	159 15	174 15	189 15
38	9 30	24 30	39 30	54 30	69 30	84 30	99 30	114 30	129 30	144 30	159 30	174 30	189 30
39	9 45	24 45	39 45	54 45	69 45	84 45	99 45	114 45	129 45	144 45	159 45	174 45	189 45
40	10 00	25 00	40 00	55 00	70 00	85 00	100 00	115 00	130 00	145 00	160 00	175 00	190 00
41	10 15	25 15	40 15	55 15	70 15	85 15	100 15	115 15	130 15	145 15	160 15	175 15	190 15
42	10 30	25 30	40 30	55 30	70 30	85 30	100 30	115 30	130 30	145 30	160 30	175 30	190 30
43	10 45	25 45	40 45	55 45	70 45	85 45	100 45	115 45	130 45	145 45	160 45	175 45	190 45
44	11 00	26 00	41 00	56 00	71 00	86 00	101 00	116 00	131 00	146 00	161 00	176 00	191 00
45	11 15	26 15	41 15	56 15	71 15	86 15	101 15	116 15	131 15	146 15	161 15	176 15	191 15
46	11 30	26 30	41 30	56 30	71 30	86 30	101 30	116 30	131 30	146 30	161 30	176 30	191 30
47	11 45	26 45	41 45	56 45	71 45	86 45	101 45	116 45	131 45	146 45	161 45	176 45	191 45
48	12 00	27 00	42 00	57 00	72 00	87 00	102 00	117 00	132 00	147 00	162 00	177 00	192 00
49	12 15	27 15	42 15	57 15	72 15	87 15	102 15	117 15	132 15	147 15	162 15	177 15	192 15
50	12 30	27 30	42 30	57 30	72 30	87 30	102 30	117 30	132 30	147 30	162 30	177 30	192 30
51	12 45	27 45	42 45	57 45	72 45	87 45	102 45	117 45	132 45	147 45	162 45	177 45	192 45
52	13 00	28 00	43 00	58 00	73 00	88 00	103 00	118 00	133 00	148 00	163 00	178 00	193 00
53	13 15	28 15	43 15	58 15	73 15	88 15	103 15	118 15	133 15	148 15	163 15	178 15	193 15
54	13 30	28 30	43 30	58 30	73 30	88 30	103 30	118 30	133 30	148 30	163 30	178 30	193 30
55	13 45	28 45	43 45	58 45	73 45	88 45	103 45	118 45	133 45	148 45	163 45	178 45	193 45
56	14 00	29 00	44 00	59 00	74 00	89 00	104 00	119 00	134 00	149 00	164 00	179 00	194 00
57	14 15	29 15	44 15	59 15	74 15	89 15	104 15	119 15	134 15	149 15	164 15	179 15	194 15
58	14 30	29 30	44 30	59 30	74 30	89 30	104 30	119 30	134 30	149 30	164 30	179 30	194 30
59	14 45	29 45	44 45	59 45	74 45	89 45	104 45	119 45	134 45	149 45	164 45	179 45	194 45
60	15 00	30 00	45 00	60 00	75 00	90 00	105 00	120 00	135 00	150 00	165 00	180 00	195 00

Note : To convert seconds of time , use the first column for the number of seconds and the second column for the converted value in <u>minutes and seconds</u> of arc ; for example 33 seconds of time = 8′15″ in arc .

CONVERSION OF ARC TO TIME

° / ′	h m / m s	° / ′	h m / m s	°	h m	°	h m	°	h m	°	h m	″	s
0	0 00	30	2 00	60	4 00	90	6 00	120	8 00	150	10 00	0	0.00
1	0 04	31	2 04	61	4 04	91	6 04	121	8 04	151	10 04	2	0.13
2	0 08	32	2 08	62	4 08	92	6 08	122	8 08	152	10 08	4	0.27
3	0 12	33	2 12	63	4 12	93	6 12	123	8 12	153	10 12	6	0.40
4	0 16	34	2 16	64	4 16	94	6 16	124	8 16	154	10 16	8	0.53
5	0 20	35	2 20	65	4 20	95	6 20	125	8 20	155	10 20	10	0.67
6	0 24	36	2 24	66	4 24	96	6 24	126	8 24	156	10 24	12	0.80
7	0 28	37	2 28	67	4 28	97	6 28	127	8 28	157	10 28	14	0.93
8	0 32	38	2 32	68	4 32	98	6 32	128	8 32	158	10 32	16	1.07
9	0 36	39	2 36	69	4 36	99	6 36	129	8 36	159	10 36	18	1.20
10	0 40	40	2 40	70	4 40	100	6 40	130	8 40	160	10 40	20	1.33
11	0 44	41	2 44	71	4 44	101	6 44	131	8 44	161	10 44	22	1.47
12	0 48	42	2 48	72	4 48	102	6 48	132	8 48	162	10 48	24	1.60
13	0 52	43	2 52	73	4 52	103	6 52	133	8 52	163	10 52	26	1.73
14	0 56	44	2 56	74	4 56	104	6 56	134	8 56	164	10 56	28	1.87
15	1 00	45	3 00	75	5 00	105	7 00	135	9 00	165	11 00	30	2.00
16	1 04	46	3 04	76	5 04	106	7 04	136	9 04	166	11 04	32	2.13
17	1 08	47	3 08	77	5 08	107	7 08	137	9 08	167	11 08	34	2.27
18	1 12	48	3 12	78	5 12	108	7 12	138	9 12	168	11 12	36	2.40
19	1 16	49	3 16	79	5 16	109	7 16	139	9 16	169	11 16	38	2.53
20	1 20	50	3 20	80	5 20	110	7 20	140	9 20	170	11 20	40	2.67
21	1 24	51	3 24	81	5 24	111	7 24	141	9 24	171	11 24	42	2.80
22	1 28	52	3 28	82	5 28	112	7 28	142	9 28	172	11 28	44	2.93
23	1 32	53	3 32	83	5 32	113	7 32	143	9 32	173	11 32	46	3.07
24	1 36	54	3 36	84	5 36	114	7 36	144	9 36	174	11 36	48	3.20
25	1 40	55	3 40	85	5 40	115	7 40	145	9 40	175	11 40	50	3.33
26	1 44	56	3 44	86	5 44	116	7 44	146	9 44	176	11 44	52	3.47
27	1 48	57	3 48	87	5 48	117	7 48	147	9 48	177	11 48	54	3.60
28	1 52	58	3 52	88	5 52	118	7 52	148	9 52	178	11 52	56	3.73
29	1 56	59	3 56	89	5 56	119	7 56	149	9 56	179	11 56	58	3.87
30	2 00	60	4 00	90	6 00	120	8 00	150	10 00	180	12 00	60	4.00

Degrees of arc convert to hours and minutes of time ; minutes of arc convert to minutes and seconds of time . See right hand column for conversion of seconds of arc to seconds of time .

SIDEREAL CONVERSIONS

		Longitude						
		0° 00′	2° 30′	5° 00′	7° 30′	10° 00′	12° 30′	15° 00′
		Minutes						
Long.	Hours	0	10	20	30	40	50	60
°		m s	m s	m s	m s	m s	m s	m s
0	0	0 00	0 02	0 03	0 05	0 07	0 08	0 10
15	1	0 10	0 11	0 13	0 15	0 16	0 18	0 20
30	2	0 20	0 21	0 23	0 25	0 26	0 28	0 30
45	3	0 30	0 31	0 33	0 34	0 36	0 38	0 39
60	4	0 39	0 41	0 43	0 44	0 46	0 48	0 49
75	5	0 49	0 51	0 53	0 54	0 56	0 57	0 59
90	6	0 59	1 01	1 02	1 04	1 06	1 07	1 09
105	7	1 09	1 11	1 12	1 14	1 15	1 17	1 19
120	8	1 19	1 20	1 22	1 24	1 25	1 27	1 29
135	9	1 29	1 30	1 32	1 31	1 35	1 37	1 38
150	10	1 38	1 40	1 42	1 43	1 45	1 47	1 48
165	11	1 48	1 50	1 52	1 53	1 55	1 56	1 58
180	12	1 58	2 00	2 01	2 03	2 05	2 06	2 08

Sidereal into mean solar time : To be subtracted from a sidereal time interval : Argument , hours and minutes of sidereal interval .

Mean solar into sidereal time : To be added to a mean time interval : Argument , hours and minutes of mean time interval .

For any stellar observation : Amount to be subtracted from the Greenwich mean time of transit or elongation to obtain local mean time : Argument , longitude west from Greenwich ; add for longitudes east from Greenwich .

FOR FINDING THE VERTICAL AND HORIZONTAL ANGLES OF A STAR

Natural Sines, Cosines, and Tangents

For sin tan	tan	diff	sin	diff	For cos only
0°00'	.0000	44	.0000	44	90°00'
15'	.0044	43	.0044	43	45'
30'	.0087	44	.0087	44	30'
45'	.0131	44	.0131	44	15'
1°00'	.0175	43	.0175	43	89°00'
15'	.0218	44	.0218	44	45'
30'	.0262	44	.0262	43	30'
45'	.0306	43	.0305	44	15'
2°00'	.0349	44	.0349	44	88°00'
15'	.0393	44	.0393	43	45'
30'	.0437	43	.0436	44	30'
45'	.0480	44	.0480	43	15'
3°00'	.0524	44	.0523	44	87°00'
15'	.0568	44	.0567	43	45'
30'	.0612	43	.0610	44	30'
45'	.0655	44	.0654	44	15'
4°00'	.0699	44	.0698	43	86°00'
15'	.0743	44	.0741	44	45'
30'	.0787	44	.0785	43	30'
45'	.0831	44	.0828	44	15'
5°00'	.0875	44	.0872	43	85°00'
15'	.0919	44	.0915	43	45'
30'	.0963	44	.0958	44	30'
45'	.1007	44	.1002	43	15'
6°00'	.1051	44	.1045	44	84°00'
15'	.1095	44	.1089	43	45'
30'	.1139	45	.1132	43	30'
45'	.1184	44	.1175	44	15'
7°00'	.1228	44	.1219	43	83°00'
15'	.1272	45	.1262	43	45'
30'	.1317	44	.1305	44	30'
45'	.1361	44	.1349	43	15'
8°00'	.1405	45	.1392	43	82°00'
15'	.1450	45	.1435	43	45'
30'	.1495	44	.1478	43	30'
45'	.1539	45	.1521	43	15'
9°00'	.1584	45	.1564	43	81°00'
15'	.1629	44	.1607	43	45'
30'	.1673	45	.1650	43	30'
45'	.1718	45	.1693	43	15'
10°00'	.1763	45	.1736	43	80°00'
15'	.1808	45	.1779	43	45'
30'	.1853	46	.1822	43	30'
45'	.1899	45	.1865	43	15'
11°00'	.1944	45	.1908	43	79°00'
15'	.1989	46	.1951	43	45'
30'	.2035	45	.1994	42	30'
45'	.2080	46	.2036	43	15'
12°00'	.2126	45	.2079	43	78°00'
15'	.2171	46	.2122	42	45'
30'	.2217	46	.2164	43	30'
45'	.2263	46	.2207	43	15'
13°00'	.2309	46	.2250	42	77°00'
15'	.2355	46	.2292	42	45'
30'	.2401	46	.2334	43	30'
45'	.2447	46	.2377	42	15'
14°00'	.2493	47	.2419	43	76°00'
15'	.2540	46	.2462	42	45'
30'	.2586	47	.2504	42	30'
45'	.2633	46	.2546	42	15'
15°00'	.2679		.2588		75°00'
For sin tan	tan		cos		For cos only

For sin tan	tan	diff	sin	diff	For cos only
15°00'	.2679	47	.2588	42	75°00'
15'	.2726	47	.2630	42	45'
30'	.2773	47	.2672	42	30'
45'	.2820	47	.2714	42	15'
16°00'	.2867	48	.2756	42	74°00'
15'	.2915	47	.2798	42	45'
30'	.2962	48	.2840	42	30'
45'	.3010	47	.2882	42	15'
17°00'	.3057	48	.2924	41	73°00'
15'	.3105	48	.2965	42	45'
30'	.3153	48	.3007	42	30'
45'	.3201	48	.3049	41	15'
18°00'	.3249	49	.3090	42	72°00'
15'	.3298	48	.3132	41	45'
30'	.3346	49	.3173	41	30'
45'	.3395	48	.3214	42	15'
19°00'	.3443	49	.3256	41	71°00'
15'	.3492	49	.3297	41	45'
30'	.3541	49	.3338	41	30'
45'	.3590	50	.3379	41	15'
20°00'	.3640	49	.3420	41	70°00'
15'	.3689	50	.3461	41	45'
30'	.3739	50	.3502	41	30'
45'	.3789	50	.3543	41	15'
21°00'	.3839	50	.3584	40	69°00'
15'	.3889	50	.3624	41	45'
30'	.3939	51	.3665	41	30'
45'	.3990	50	.3706	40	15'
22°00'	.4040	51	.3746	40	68°00'
15'	.4091	51	.3786	41	45'
30'	.4142	51	.3827	40	30'
45'	.4193	52	.3867	40	15'
23°00'	.4245	51	.3907	40	67°00'
15'	.4296	52	.3947	40	45'
30'	.4348	52	.3987	40	30'
45'	.4400	52	.4027	40	15'
24°00'	.4452	53	.4067	40	66°00'
15'	.4505	52	.4107	40	45'
30'	.4557	53	.4147	40	30'
45'	.4610	53	.4187	39	15'
25°00'	.4663	53	.4226	40	65°00'
15'	.4716	54	.4266	39	45'
30'	.4770	53	.4305	39	30'
45'	.4823	54	.4344	40	15'
26°00'	.4877	54	.4384	39	64°00'
15'	.4931	55	.4423	39	45'
30'	.4986	54	.4462	39	30'
45'	.5040	55	.4501	39	15'
27°00'	.5095	55	.4540	39	63°00'
15'	.5150	56	.4579	38	45'
30'	.5206	55	.4617	39	30'
45'	.5261	56	.4656	39	15'
28°00'	.5317	56	.4695	38	62°00'
15'	.5373	57	.4733	39	45'
30'	.5430	56	.4772	38	30'
45'	.5486	57	.4810	38	15'
29°00'	.5543	57	.4848	38	61°00'
15'	.5600	58	.4886	38	45'
30'	.5658	57	.4924	38	30'
45'	.5715	59	.4962	38	15'
30°00'	.5774		.5000		60°00'
For sin tan	tan		cos		For cos only

For sin tan	tan	diff	sin	diff	For cos only
30°00'	.5774	58	.5000	38	60°00'
15'	.5832	58	.5038	37	45'
30'	.5890	59	.5075	38	30'
45'	.5949	60	.5113	37	15'
31°00'	.6009	59	.5150	38	59°00'
15'	.6068	60	.5188	37	45'
30'	.6128	60	.5225	37	30'
45'	.6188	61	.5262	37	15'
32°00'	.6249	61	.5299	37	58°00'
15'	.6310	61	.5336	37	45'
30'	.6371	61	.5373	37	30'
45'	.6432	62	.5410	36	15'
33°00'	.6494	62	.5446	37	57°00'
15'	.6556	63	.5483	36	45'
30'	.6619	63	.5519	37	30'
45'	.6682	63	.5556	36	15'
34°00'	.6745	64	.5592	36	56°00'
15'	.6809	64	.5628	36	45'
30'	.6873	64	.5664	36	30'
45'	.6937	65	.5700	36	15'
35°00'	.7002	65	.5736	35	55°00'
15'	.7067	66	.5771	36	45'
30'	.7133	66	.5807	35	30'
45'	.7199	66	.5842	36	15'
36°00'	.7265	67	.5878	35	54°00'
15'	.7332	68	.5913	35	45'
30'	.7400	67	.5948	35	30'
45'	.7467	69	.5983	35	15'
37°00'	.7536	68	.6018	35	53°00'
15'	.7604	69	.6053	35	45'
30'	.7673	70	.6088	34	30'
45'	.7743	70	.6122	35	15'
38°00'	.7813	70	.6157	34	52°00'
15'	.7883	71	.6191	34	45'
30'	.7954	72	.6225	34	30'
45'	.8026	72	.6259	34	15'
39°00'	.8098	72	.6293	34	51°00'
15'	.8170	73	.6327	34	45'
30'	.8243	74	.6361	33	30'
45'	.8317	74	.6394	34	15'
40°00'	.8391	75	.6428	33	50°00'
15'	.8466	75	.6461	33	45'
30'	.8541	76	.6494	34	30'
45'	.8617	76	.6528	33	15'
41°00'	.8693	77	.6561	32	49°00'
15'	.8770	77	.6593	33	45'
30'	.8847	78	.6626	33	30'
45'	.8925	79	.6659	32	15'
42°00'	.9004	79	.6691	33	48°00'
15'	.9083	80	.6724	32	45'
30'	.9163	81	.6756	32	30'
45'	.9244	81	.6788	32	15'
43°00'	.9325	82	.6820	32	47°00'
15'	.9407	83	.6852	32	45'
30'	.9490	83	.6884	31	30'
45'	.9573	84	.6915	32	15'
44°00'	.9657	85	.6947	31	46°00'
15'	.9742	85	.6978	31	45'
30'	.9827	86	.7009	31	30'
45'	.9913	87	.7040	31	15'
45°00'	1.0000		.7071		45°00'
For sin tan	tan		cos		For cos only

On the meridian, the vertical angle: $h = 90° - \varphi \pm \delta$

At any hour angle: $\sin h = \cos t \cos \varphi \cos \delta + \sin \varphi \sin \delta$

The product: "$\sin \varphi \sin \delta$" is negative for south declinations.

The product: "$\cos t \cos \varphi \cos \delta$" is negative for hour angles exceeding six hours or 90°.

FOR FINDING THE VERTICAL AND HORIZONTAL ANGLES OF A STAR

Natural Sines, Cosines, and Tangents

For sin tan	tan		sin		For cos only	For sin tan	tan		sin		For cos only	For sin	sin		For cos only
45°00'	1.0000	88	.7071	31	45°00'	60°00'	1.7321	175	.8660	22	30°00'	75°00'	.9659	11	15°00'
15'	1.0088	88	.7102	31	45'	15'	1.7496	179	.8682	22	45'	15'	.9670	11	45'
30'	1.0176	89	.7133	30	30'	30'	1.7675	181	.8704	21	30'	30'	.9681	11	30'
45'	1.0265	90	.7163	30	15'	45'	1.7856	184	.8725	21	15'	45'	.9692	11	15'
46°00'	1.0355	91	.7193	31	44°00'	61°00'	1.8040	188	.8746	21	29°00'	76°00'	.9703	10	14°00'
15'	1.0446	92	.7224	30	45'	15'	1.8228	190	.8767	21	45'	15'	.9713	11	45'
30'	1.0538	92	.7254	30	30'	30'	1.8418	193	.8788	21	30'	30'	.9724	10	30'
45'	1.0630	94	.7284	30	15'	45'	1.8611	196	.8809	20	15'	45'	.9734	10	15'
47°00'	1.0724	94	.7314	29	43°00'	62°00'	1.8807	200	.8829	21	28°00'	77°00'	.9744	9	13°00'
15'	1.0818	95	.7343	30	45'	15'	1.9007	203	.8850	20	45'	15'	.9753	10	45'
30'	1.0913	96	.7373	29	30'	30'	1.9210	206	.8870	20	30'	30'	.9763	9	30'
45'	1.1009	97	.7402	29	15'	45'	1.9416	210	.8890	20	15'	45'	.9772	9	15'
48°00'	1.1106	98	.7431	30	42°00'	63°00'	1.9626	214	.8910	20	27°00'	78°00'	.9781	9	12°00'
15'	1.1204	99	.7461	29	45'	15'	1.9840	217	.8930	19	45'	15'	.9790	9	45'
30'	1.1303	100	.7490	28	30'	30'	2.0057	221	.8949	20	30'	30'	.9799	9	30'
45'	1.1403	101	.7518	29	15'	45'	2.0278	225	.8969	19	15'	45'	.9808	8	15'
49°00'	1.1504	102	.7547	29	41°00'	64°00'	2.0503	229	.8988	19	26°00'	79°00'	.9816	9	11°00'
15'	1.1606	102	.7576	28	45'	15'	2.0732	233	.9007	19	45'	15'	.9825	8	45'
30'	1.1708	104	.7604	28	30'	30'	2.0965	238	.9026	19	30'	30'	.9833	7	30'
45'	1.1812	106	.7632	28	15'	45'	2.1203	242	.9045	18	15'	45'	.9840	8	15'
50°00'	1.1918	106	.7660	28	40°00'	65°00'	2.1445	247	.9063	18	25°00'	80°00'	.9848	8	10°00'
15'	1.2024	107	.7688	28	45'	15'	2.1692	251	.9081	19	45'	15'	.9856	7	45'
30'	1.2131	108	.7716	28	30'	30'	2.1943	256	.9100	18	30'	30'	.9863	7	30'
45'	1.2239	110	.7744	27	15'	45'	2.2199	261	.9118	17	15'	45'	.9870	7	15'
51°00'	1.2349	111	.7771	28	39°00'	66°00'	2.2460	267	.9135	18	24°00'	81°00'	.9877	7	9°00'
15'	1.2460	112	.7799	27	45'	15'	2.2727	271	.9153	18	45'	15'	.9884	6	45'
30'	1.2572	113	.7826	27	30'	30'	2.2998	278	.9171	17	30'	30'	.9890	7	30'
45'	1.2685	114	.7853	27	15'	45'	2.3276	283	.9188	17	15'	45'	.9897	6	15'
52°00'	1.2799	116	.7880	27	38°00'	67°00'	2.3559	288	.9205	17	23°00'	82°00'	.9903	6	8°00'
15'	1.2915	117	.7907	27	45'	15'	2.3847	295	.9222	17	45'	15'	.9909	5	45'
30'	1.3032	119	.7934	26	30'	30'	2.4142	301	.9239	16	30'	30'	.9914	6	30'
45'	1.3151	119	.7960	26	15'	45'	2.4443	308	.9255	17	15'	45'	.9920	5	15'
53°00'	1.3270	122	.7986	27	37°00'	68°00'	2.4751	314	.9272	16	22°00'	83°00'	.9925	6	7°00'
15'	1.3392	122	.8013	26	45'	15'	2.5065	321	.9288	16	45'	15'	.9931	5	45'
30'	1.3514	124	.8039	25	30'	30'	2.5386	329	.9304	16	30'	30'	.9936	5	30'
45'	1.3638	126	.8064	26	15'	45'	2.5715	336	.9320	16	15'	45'	.9941	4	15'
54°00'	1.3764	127	.8090	26	36°00'	69°00'	2.6051	344	.9336	15	21°00'	84°00'	.9945	5	6°00'
15'	1.3891	128	.8116	25	45'	15'	2.6395	351	.9351	16	45'	15'	.9950	4	45'
30'	1.4019	131	.8141	25	30'	30'	2.6746	360	.9367	15	30'	30'	.9954	4	30'
45'	1.4150	131	.8166	26	15'	45'	2.7106	369	.9382	15	15'	45'	.9958	4	15'
55°00'	1.4281	134	.8192	24	35°00'	70°00'	2.7475	377	.9397	15	20°00'	85°00'	.9962	4	5°00'
15'	1.4415	135	.8216	25	45'	15'	2.7852	387	.9412	14	45'	15'	.9966	3	45'
30'	1.4550	137	.8241	25	30'	30'	2.8239	397	.9426	15	30'	30'	.9969	4	30'
45'	1.4687	139	.8266	24	15'	45'	2.8636	406	.9441	14	15'	45'	.9973	3	15'
56°00'	1.4826	140	.8290	25	34°00'	71°00'	2.9042	417	.9455	14	19°00'	86°00'	.9976	3	4°00'
15'	1.4966	142	.8315	24	45'	15'	2.9459	428	.9469	14	45'	15'	.9979	2	45'
30'	1.5108	145	.8339	24	30'	30'	2.9887	439	.9483	14	30'	30'	.9981	3	30'
45'	1.5253	146	.8363	24	15'	45'	3.0326	451	.9497	14	15'	45'	.9984	2	15'
57°00'	1.5399	148	.8387	23	33°00'	72°00'	3.0777	463	.9511	13	18°00'	87°00'	.9986	2	3°00'
15'	1.5547	150	.8410	24	45'	15'	3.1240	476	.9524	13	45'	15'	.9988	2	45'
30'	1.5697	152	.8434	23	30'	30'	3.1716	489	.9537	13	30'	30'	.9990	2	30'
45'	1.5849	154	.8457	23	15'	45'	3.2205	504	.9550	13	15'	45'	.9992	2	15'
58°00'	1.6003	157	.8480	24	32°00'	73°00'	3.2709	517	.9563	13	17°00'	88°00'	.9994	1	2°00'
15'	1.6160	159	.8504	22	45'	15'	3.3226	533	.9576	12	45'	15'	.9995	2	45'
30'	1.6319	160	.8526	23	30'	30'	3.3759	549	.9588	12	30'	30'	.9997	1	30'
45'	1.6479	164	.8549	23	15'	45'	3.4308	566	.9600	13	15'	45'	.9998	0	15'
59°00'	1.6643	165	.8572	22	31°00'	74°00'	3.4874	583	.9613	12	16°00'	89°00'	.9998	1	1°00'
15'	1.6808	169	.8594	22	45'	15'	3.5457	602	.9625	11	45'	15'	.9999	1	45'
30'	1.6977	170	.8616	22	30'	30'	3.6059	621	.9636	12	30'	30'	1.0000	0	30'
45'	1.7147	174	.8638	22	15'	45'	3.6680	641	.9648	11	15'	45'	1.0000	0	15'
60°00'	1.7321		.8660		30°00'	75°00'	3.7321		.9659		15°00'	90°00'	1.0000		0°00'
For sin tan	tan		cos		For cos only	For sin tan	tan		cos		For cos only	For sin	cos		For cos only

The horizontal angle may be found from the equation: $\text{Cos } A = \frac{\sin \delta}{\cos \varphi \cos h} - \tan \varphi \tan h$

"Sin δ" is negative for south declinations.

If the result for "cos A" is $\begin{Bmatrix}\text{positive}\\\text{negative}\end{Bmatrix}$ the horizontal angle counts from the $\begin{Bmatrix}\text{north.}\\\text{south.}\end{Bmatrix}$

PREPARING FOR THE OBSERVATIONS

The modern solar transit, as developed for surveying the public lands, affords a ready determination of the factors of time, latitude, and azimuth, which are the starting values employed in the stellar observations. The latter are designed to supply the desired refinements in the values, better than the limits of the solar unit. A carefully determined meridian is used in making the instrumental adjustments and tests, preliminary to the running of the lines, and the direction of the latter is verified at frequent intervals.

Since few solar transits are in general use, consideration is to be given to the preliminary steps to be taken when the factors of time, latitude, and azimuth are unknown, or are only roughly approximate. If nothing is to be assumed as known, or approximate, it is well to begin with the equal-altitude observation on the sun, or one of the known bright stars, by which the latitude, azimuth, and time may all be derived.

If the uncertainty in latitude is not more than 2′ or 3′, an altitude observation of the sun, or any known bright star, may be made, from which to derive preliminary values for time and azimuth, using the approximate latitude as the factor until its value can be suitably corrected. An observation of Polaris at elongation may be made without exact data as to the time or latitude.

An interpretation of the terms "approximate" and "rough" may be helpful in clarifying what is intended. These terms have been used with reference to the preliminary values for time, latitude, and azimuth, to be regarded as more or less reliable for the identification of a star by vertical and horizontal angles. For this purpose and for a starlight period, a rough estimate based upon incomplete data, employed with good judgment, may allow a fairly wide tolerance and yet be entirely acceptable for the identification of a star without the slightest doubt. However, if a daylight or twilight observing period is proposed the setting positions should be sufficiently good to bring the star within the middle-third of the telescope. The time of passage across the field is slightly more than 4 minutes.

Some practice in making the observations by starlight is needed, or will be helpful, before making the twilight or daylight observations, and for the latter it is desirable to prepare the data for several positions for the sequence of settings at intervals that will allow for the reading of angles and the instrumental reversals. Obviously, the twilight or daylight observation will depend very largely upon the clearness of the atmosphere.

In all cases the finding positions are for the identification of a star, and having served that purpose the observation proceeds with the required care in all detail. The arrangement of the data and the suggestions as to the observing plan are intended to simplify the steps. The methods for a well-balanced observing program are good for results within ± 6 seconds of time; ± 15″ in latitude and azimuth; for vernier readings to the nearest 30″; due care being given to the necessary refinements in the observing and in the reductions; these limits are with reference to the one-minute transit ordinarily supplied to the field parties.

The setting positions for the instrument, in vertical angle (v or h for this purpose), and in horizontal angle (A) counting from the meridian (or from an approximate north and south line) are derived from the equations after having determined the hour angle (t) for the anticipated moment for the observation.

The 4-place tables may be used to shorten the work, as being sufficient for the star's identification or finding.

Example.

Star: 6-10 1.1
α Tauri (Aldebaran)
δ : +16°27′

φ : Approximate latitude: 35°18′

t : Anticipated hour angle: 4^h43^m (70°45′)

$$\sin h = \cos t \cos \varphi \cos \delta + \sin \varphi \sin \delta$$

	cos	sin	
t =	.330		
φ =	.816	.578	
δ =	.959	.283	
	.2582	.1636	(Products)
		.2582	
sin h =		.4218	(Sum)
h =	24°57′		

$$\cos A = \frac{\sin \delta}{\cos \varphi \cos h} - \tan \varphi \tan h$$

	cos	sin	tan	
	.816		.708	
		.283		
	.907	____	.465	
	.7401		.3292	(Products)
		.3824	.3824	(Fraction)
cos A =			.0532	(Diff. +)

A = 86°57′ (Counting from the north)

In general make each reading to the nearest third place, regarding the values as merely approximate. The results are good as finding positions, or for the star's identification. The true values are obtained by careful reduction of the observations.

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